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The effects of channel stability on benthic macroinvertebrates in southeastern Louisiana streams

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THE EFFECTS OF CHANNEL STABILITY ON BENTHIC MACROINVERTEBRATES IN SOUTHEASTERN LOUISIANA STREAMS

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Abstract

Water chemistry, habitat quality, and channel stability interact to influence a stream's biological integrity. The goal of this project was to assess how channel stability, together with other physicochemical stream measurements, are associated with the structure and abundance of resident macroinvertebrate communities. I recorded multiple physicochemical parameters and calculated a Pfankuch habitat stability index monthly for a year at potential reference streams in southeastern Louisiana. I assessed the relationships of channels stability with measured physicochemical parameters with multiple regression and principle components analysis. Mixed model multivariate analysis of variance was used to determine associations of habitat characteristics with resident macroinvertebrate genera and communities.

In the September woody debris sample, macroinvertebrate abundance was generally determined by habitat factors that describe stream metabolism and woody debris habitat, in the May woody debris sample, abundances of xylophilic macroinvertebrates appeared to be more associated with geomorphologic components of a stream rather than stream productivity. The PSI was associated with multiple habitat variables, and variability in channel stability between streams was found to affect macroinvertebrate genera and community abundances in both seasons regardless of stream size or stream productivity. Because of the high correlations between the PSI, other habitat variables, and macroinvertebrate abundance, I believe the PSI should be used in future studies that focus on developing a biotic index in low gradient Louisiana streams. Integrating biological monitoring, more precise habitat measurements, and current physicochemical monitoring protocols will result in managers having more tools to evaluate stream degradation and protect Louisiana's waterways.

Introduction

Lotic ecosystems play an important role in landscape ecology, providing resources for aquatic and terrestrial biota and supporting the development of diverse anthropogenic land use activities. Streams drain surrounding landscapes within a watershed and provide habitats for diverse communities of bacteria, fungi, algae, macroinvertebrates, and fishes, all of which play critical roles in the energy and nutrient transformation of allochthonous inputs (Molles 2002; Allan and Castello 2007). There is little question that healthy stream systems are critical to the maintenance of human cultures and biodiversity (Molles 2002). However, anthropogenic stream modifications in the U.S. have caused great concern over the degradation of the nation's freshwater resources (Karr 1991). These concerns are clear in the Clean Water Act of 1987, the primary goal of which is "to restore and maintain the physical, chemical, and biological integrity of the nation's water" (U.S. Environmental Protection Agency 1990).

To protect water resources, the Environmental Protection Agency (EPA) mandated the development of state stream monitoring programs and Total Maximum Daily Load (TMDL) classifications of stream impairment throughout the U.S. Many states have incorporated biomonitoring programs based on macroinvertebrate or fish community composition as part of the overall protocol to determine levels of stream impairment. However, developing a biomonitoring program is dependent on characterization of reference stream (unimpaired or least impaired) conditions so that a benchmark can be developed for comparison to potentially degraded systems (Karr 1981). In addition to biological community composition, physical and chemical stream characteristics have also been used to develop reference criteria and to monitor stream health (Karr 1991). Each method has unique strengths and weaknesses, and because of their complementary nature, combining physicochemical and biotic methods in a monitoring program increases the probability of accurately describing stream degradation (Karr and Yoder 2004).

Chemical monitoring is a cost effective technique that can identify harmful toxins, elevated nutrient levels, and resulting physicochemical changes [e.g., high biochemical oxygen demand (BOD) and low dissolved oxygen (DO) levels] within a stream. However, a major drawback with physicochemically-based determination of stream impairment is that measurements typically reveal water quality information at a single point in time and do not reflect long-term stream conditions (Wilhm and Dorris 1968; Resh et al. 1996). In contrast, biological monitoring provides an assessment of biotic responses to stream conditions integrated over an extended period of time, but biological indices are subject to considerable variation, and biotic community composition may not be related to stream health (Resh et al. 1996). Perhaps most importantly, development of an effective biomonitoring program requires extensive research to determine gradients of stream conditions and biological responses in streams spanning a range of biotic integrity (Allan and Castello 2007; Morris et al. 2007).

Managers and researches have focused attention on maintaining chemical and biological integrity in streams through development of acceptable levels of various abiotic stream parameters, and by emphasizing preservation of biodiversity and stream productivity. Maintaining the physical integrity of lotic systems has typically been overlooked (Graf 2001), although physical stream impacts (e.g., increased sediment inputs) are some of the most pervasive anthropogenic disturbances in U.S. streams (Waters 1995). Physical monitoring protocols have focused on presence/absence surveys to evaluate habitat quality and habitat characteristics such as woody debris, stream vegetation, substrate size, and pool/ riffle spatial diversity that are tied to the maintenance of biological integrity (Rabeni 2000; Asmus et al.

2009). However, monitoring these physical parameters does not characterize the fluvial processes that control channel stability (Asmus et al. 2009).

In a recent paper, Asmus et al. (2009) argue that channel stability is the foundation for maintenance of habitat quality and stream health in low-gradient streams. Channel stability can be defined as a dynamic equilibrium process whereby a stream channel is neither aggrading nor degrading (Lane 1955; Rosgen 1996; Watson et al. 2002), but can also be viewed as the ability of a stream to resist and recover from disturbance and maintain its channel, floodplain, sediment composition, and overall spatial configuration (Wallace 1990; Lake 2000; Graf 2001). Both definitions are related and will ultimately be determined by the geomorphologic characteristics of a stream.

Unstable reaches are characterized by an inability to transport sediments or by a transport capacity that exceeds the sedimentation rate. The former causes excessive sediment deposition, embedded stream bottoms and channel aggradation, which result in a stream becoming disconnected from its floodplain; the latter results in eroded channel banks, scoured stream bottoms, and channel degradation, which causes stream widening, a loss of habitat heterogeneity, fewer pool habitats and decreased amounts of stored organic debris (Shields et al. 1994: Magner and Brooks 2007). Stable reaches undergo minor erosion and maintain channel morphology over time, thus providing more consistent habitat conditions for resident biological communities (Lane 1955, Southwood 1977).

Although determining channel stability is vital to understanding water chemistry, habitat quality, and biological integrity (Maddock 1999), little work has been done relating these parameters. Lenhart (2008) showed that unstable stream reaches were related to the chemical integrity of a stream through changes in sediment supply and/or changes in flow regime that resulted in increased total suspended solids, turbidity, and temperature, and reduced DO levels. Sedimentation is recognized as a major pollutant in waterways (Oschwald 1972; Dawning 1980; Shields et al. 1998), and discharge patterns have been shown to be extremely important determinants of stream biota abundance and distribution, as well as lotic system integrity (Power et al. 1995; Poff et al. 1997).

Many commonly measured physical factors (e.g., woody debris density) are thought to be particularly important in structuring stream communities (Vannote et al. 1980; Resh 1988; Wallace and Webster 1996; McIntosh 2000), but channel stability has also been shown to be strongly associated with several habitat characteristics, specifically channel flow, sediment deposition, bank stability, vegetative protection, riparian vegetative zone width, and embeddedness (Mazeika et al. 2004). In addition, unstable stream reaches have greater monthly variation in depth, flow velocity, temperature, and substrate composition and movement (Death and Winterbourn 1994; Fowler and Death 2000), and geomorphologic and hydrologic stability are thought to influence the magnitude and duration of physical disturbance effects and the ability of a stream channel to resist and recover from disturbance events (Wallace 1990; Lake 2000).

In summary, stream stability can affect variability in habitat characteristics among stream reaches, as well as among streams, ultimately determining stream resilience and resistance to disturbance events. Clearly, this habitat stability is also reflected in the abundances and species composition of resident biotic communities, notably periphyton, macroinvertebrates, and fishes (Stevenson 1990; Death and Winterbourn 1995a; Lake 2000; McIntosh 2000). The persistence and diversity of stream faunal communities are consequences of each species' ability to adapt to predictable long term habitat characteristics and to evolve life history strategies that can overcome natural variation in these systems (Connel 1978; Huston 1979). In this study, I was concerned not only with the relative habitat stability of my study streams, but also the role that aquatic habitat stability plays in structuring lotic communities in southeastern Louisiana streams. Although several organisms could be used to study the relationship between stream channel stability and biotic composition, benthic macroinvertebrates offer several advantages over other taxonomic groups (Resh et al. 1996): they are ubiquitous stream organisms with diverse and adaptable life histories that are closely linked to their environment (Buttler 1984; Mazeika et al. 2004; Allan and Castello 2007); they play essential roles in the energy flow and nutrient cycling processes that drive lotic systems (Woodcock and Huryn 2007); and they are an important link between primary energy sources (e.g., allochthonous organic mater or autochthonous periphyton production) and higher order aquatic consumers (e.g., invertivorous stream fishes).

Macroinvertebrates are sensitive to variables that reflect channel instability, such as reductions in habitat diversity (Maul et al. 2004), changes in the frequency and intensity of discharge (Gore 1977, 1978, Fisher 1983) and embeddedness of coarse substrates from sedimentation (Lenat et al. 1981). Macroinvertebrates have also been show to be sensitive to differences in temperature, (Cudney and Wallace 1980; Kondratieff and Voshell 1980; Webster et al. 1983; Sweeney 1984), DO (Goredon and Wallace 1975), substrate size (Crisp and Crisp 1974; Rabeni and Minshall 1977; Reice 1981; Gurtz and Wallace 1984; Huryn and Wallace 1987), and fine and coarse particulate organic matter (Winterbourn et al. 1981), all of which can vary with changes in channel stability. In sandy bottom streams, woody debris is a stable and extremely important substrate for a diversity of macroinvertebrate taxa (Cudney and Wallace 1980; Wallace and Benke 1984; Benke et al. 1985; Smock et al. 1989; Benke and Wallace 1990; Benke and Wallace 2003; Kaller 2009; Kaller and Kelso, in press), and channel stability can also play an important role in providing and maintaining suitable (i.e., unburied) habitat for epixylic organisms.

Given their life histories and habitat associations, macroinvertebrates are also well suited for studying the effects of geomorphic impairment on lotic systems (Malmqvist 2002). Death and Winterbourn (1994) found that macroinvertebrate communities showed greater persistence at stable sites, and much more variability in relative abundance at unstable sites. This is consistent with the observations of Maul et al. (2004), who reported greater inter-annual variability in macroinvertebrate communities at unstable sites, as well as other studies that have reported reduced abundance and richness of benthic macroinvertebrate communities in physically-disturbed streams (Fisher et al. 1982; Robinson and Minshall 1986; Malmqvist and Otto 1987, Death and Winterbourn 1995a). Importantly, Mazeika et al. (2004) found that stable channels supported greater abundances of ephemeropteran, plecopteran, and trichopteran (EPT) taxa that are often used in biomonitoring studies because their presence in the macroinvertebrate community generally reflects less-impaired stream conditions.

Water chemistry, habitat quality, and channel stability interact to influence a stream's biological integrity (Maddock 1999). Including channel stability with water chemistry and habitat quality in a monitoring program for low gradient streams would benefit managers when determining reference conditions for stream monitoring programs, compiling baseline data to use in comparisons of possible future impairments, and when trying to determine causes of impairments for development of TMDLs (Asmus et al. 2009). In that vein, this study uses assessments of channel stability, water chemistry, and habitat quality to assess potential biological indicators at reference sites for streams in southeastern Louisiana.

Louisiana streams are typically characterized by low gradients, silt and sand substrates, large amounts of woody debris, and low DO concentrations (Welch 1942; Holland et al. 1952). Current ecoregion assessments classify Louisiana into six level IV ecoregions, which are divided into sub-ecoregions, each with its own unique characteristics (Daigle et al. 2006). My study was done in the Terrace Uplands ecoregion, which includes streams that are characterized by relatively coarser substrates, steeper gradients, narrower channels, denser riparian vegetation, lower water temperatures, and greater turbulence-driven DO levels than other systems in the state (Welch 1942; Holland 1952; Felley 1993). This area is ideal for studying the relationships between stream physicochemistry and the structure of resident macroinvertebrate communities, as habitat conditions range from streams with abundant woody debris, narrow channels and sandy substrates to streams characterized by higher DO levels, open canopies, and gravel substrates.

Although stream monitoring by the Louisiana Department of Environmental Quality (LDEQ) currently relies on physicochemical evaluations, efforts are continuing to establish biocriteria for fishes to assess stream health. Bioassessment criteria for benthic macroinvertebrates have not been applied (LDEQ 2006), although such a program could be highly beneficial to the assessment of stream quality within the state (Kaller 2005). Few studies have addressed the effects of environmental conditions on benthic macroinvertebrates in Louisiana streams (Dewalt 1995; Dewalt 1997; Kaller 2005; Williams et al. 2005; Kaller and Kelso 2006 a, b, c, d; Kaller and Kelso 2007, Williams et al. 2007), although habitat characteristics have been reported to play an important role in structuring these communities, and detailed habitat analyses have been prescribed for monitoring these systems (Williams et al. 2005; Kaller and Kelso 2007; Kaller 2009). Including measurements of channel stability in the evaluation protocols for assessing streams integrity could help determine sources of variation in reference conditions and allow for a better understanding of the relative importance of natural and anthropogenic factors in determining macroinvertebrate community structure (Asmus et al. 2009).

The goal of this project was to assess how channel stability correlated with other physicochemical stream measurements and determine the most important associations between measured physicochemical variables and the structure of resident macroinvertebrate communities. More specifically, my objectives were to: 1) assess how channel stability correlated with physicochemical characteristics in southeastern Louisiana streams; and 2) determine the relationships among habitat characteristics, stream stability, and the community composition and environmental sensitivities of resident macroinvertebrates. Results of my study will hopefully help managers determine the best attainable biological criteria for streams in the Terrace Upland ecoregion.

Methods

Study Sites

I established study sites in first to third order wadeable streams in Lawrence, Bogue Lusa, and Pushepatapa creeks located in Louisiana's southeastern plains ecoregion (Figure 1). I used a Pfankuch stability index (PSI) (described below) in a preliminary study to select nine study sites that provided a potential range in stability and associated habitat and biotic characteristics. Three sites were established in each of the study streams and were located near enough to each other so that they should have been affected by similar weather conditions. Habitat characteristics and water quality were sampled monthly from August 2007 to July 2008, with macroinvertebrates collected in September 2007 and May 2008.

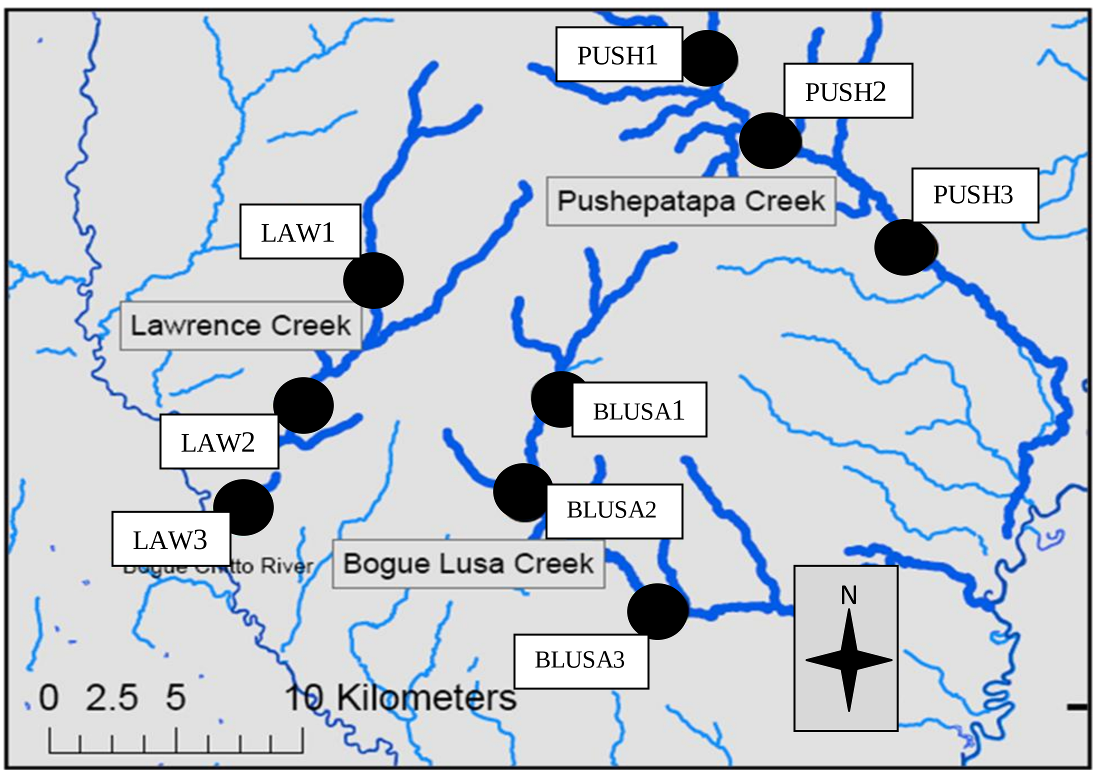

Figure 1. Study sites Lawrence 1(LAW1), Lawrence 2 (LAW2), Lawrence 3 (LAW3), Bogue Lusa 1 (BLUSA1), Bogue Lusa 2 (BLUSA2), Bogue Lusa 3 (BLUSA3), Pushepatapa 1 (PUSH1), Pushepatapa 2 (PUSH2), and Pushepatapa 3 (PUSH3) in the Terrace Uplands ecoregion, Washington Parish, Louisiana.

Data Collection

Habitat.

Death and Winterbourn (1994) stressed the importance of collecting data on as many habitat variables as possible in studies of stream channel stability. In this study, I quantified several physical parameters known to affect macroinvertebrates, including flow, temperature, woody debris, substrate size, primary productivity, and the PSI (Minshall 1984; Benke et al. 1985; Malmqvist and Otto 1987; Death and Winterbourn1 994, 1995a, and 1995b; Biggs et al. 1999; Drury and Kelso 2000; Allan and Castello 2007; Kaller and Kelso 2007; Asmus et al. 2009; Kaller 2009).

During monthly visits to each site, I recorded water temperature (^oC), pH, dissolved oxygen concentration (mg/l), specific conductance (µmhos/cm) and turbidity (NTUs) with a Hydrolab® or YSI® 6820 V2 *in situ* water quality monitor. Water samples were collected and analyzed for biological oxygen demand (BOD), total organic carbon (TOC), and total nitrogen according to procedures outlined in the American Public Health Associations' Standard Methods for the Examination of Water and Wastewater (2005). Habitat measurements [depth (cm), flow velocity (cm/sec)] were recorded at 25, 50, and 75% of the stream width along 10 transects spaced 10 m apart through each study reach with a SonteK® flow meter and graduated wading rod.

The PSI used to assess channel stability scored 15 characteristics of a stream channel's upper bank, lower bank, and substrate, and ranged from 38 (stable) to 152 (unstable) (Pfankuch 1975; Death 1994). Upper bank characteristics included land form slope, mass-wasting, debris jam potential, and vegetative bank protection. Lower bank characteristics included channel capacity, bank rock content, obstructions, and undercutting. Stream substrate characteristics included deposition, rock angularity, brightness, particle packing, bottom particle size distribution, scouring and deposition, and clinging aquatic vegetation.

Additional channel measurements included entrenchment, sinuosity, slope, and wetted width. Entrenchment was determined by a ratio of flood prone width (m) to bankfull width (m). Sinuosity was calculated as the ratio straight-line valley length (m) to stream length (m), and slope (gradient) was determined at the field sites with survey equipment (Rosgen 1994). Channel materials were distinguished as bedrock, boulders, cobble, gravel, sand, and silt/clay (Rosgen 1994), and were assessed by pebble counts with bankfull to bankfull transects set across the study reaches. In addition to pebble number along the transects, I also measured 100 pebbles to determine average diameter, which was taken along the intermediate axis of pebbles collected at set intervals along the transect, and was classified according to Wentworth (1922) size classes: < 2mm, 2-4mm, 4-8mm, 8-16mm, 16-32mm, 32-64mm, 64-128mm, 128-256mm, 256-512mm 512-1024mm, and 1024-2048mm (Potyondy and Hardy 1995).

I quantified woody debris along the 10 transects at each study site by counting each piece of wood intersected by each transect and by calculating woody debris surface area per unit area. This technique was developed by Warren and Olsen (1964) to assess logging waste, and was used by Wallace and Benke (1984) to estimate woody debris in southern coastal plain streams. The technique uses the diameter (mm) of wood debris intersecting a stream transect (Van Wagner 1968), and the diameter of woody debris is related to surface area per unit area by:

$$X_{sa} = (\prod^2/2L) \sum^n d_i$$

Where L is the transect length and d_i is the diameter of each piece of woody debris along each transect.

I also took four substrate samples with a 13-cm diameter core at each site, with two samples taken in high flow areas and two in low flow areas. Sample contents were sieved and categorized as coarse (>2mm), medium (2.5µm – 2mm), and fine (<2.5µm) substrates. The coarse category includes substrates classified in the gravel category, the medium category includes substrates classified as very coarse, coarse and medium sand, and the fine category includes substrates classified as fine sand, very fine sand and those in the silt and mud categories (Wentworth 1922). After sieving, samples were weighed, ashed, and reweighed to determine organic matter content (Death 1995a).

I measured primary productivity at each site by quantifying chlorophyll *a* as outlined by Steinman and Lamberti (1996). Two sets of 12 unglazed clay tiles were placed at each site, and each month tiles were collected and transported back to the laboratory for processing. I used a spectrophotometer to quantify light absorbance of chlorophyll *a* before and after acidification. Percent overstory cover was also quantified with a spherical densitometer.

Macroinvertebrates

I took woody debris and substrate samples in September 2007 and May 2008 to determine macroinvertebrate community composition. Samples were collected along each transect, resulting in 10 samples each of woody debris and substrate. I collected woody debris randomly as I walked upstream, with individual wood pieces picked up quickly and placed in a 250µm mesh bag (472mm x 127mm x 127mm). Substrate samples were collected with a modified Hess sampler. Woody debris and substrate samples were preserved in 90% ethanol (Kaller 2005), sorted in the laboratory and identified to the lowest practical taxon (LPT). Density of macroinvertebrates collected from woody debris was calculated as total number of macroinvertebrates/wood volume. I estimated total abundances and density (abundance per liter of substrate) of macroinvertebrate LPTs, along with family level assemblage estimates of diversity (Shannon index) and evenness (Pielou's evenness), order level % Ephemeroptera, Plecoptera, Trichoptera (% EPT), and number of genera for analysis of habitat - macroinvertebrate community relationships. I selected these community estimates because diversity (Shannon index) evenness (Pielou's evenness), % EPT, number of genera, and abundance have been used in previous studies in Louisiana (Kaller and Kelso 2006d) also, with the exception of Pielou's evenness, these community estimates have been used in similar channel stability studies (Death and Winterbourne 1995a). I selected Pielou's evenness because of its weak associations to changes in rare taxa (Beisel et al. 2003).

Statistical Analyses

The overall objective of my analyses was to investigate the potential for the PSI to predict measured habitat variables, as well as its relationships with the composition and abundance of stream benthic macroinvertebrate communities. I used individual multiple regression analyses to determine whether measured individual physicochemical variables (including the PSI) varied seasonally (linear, quadratic, or cubic functions), and to assess whether it was necessary to include sampling month as a covariate in subsequent simple linear regressions relating individual physicochemical characteristics of the streams to the PSI. The latter analysis was conducted to determine whether the PSI was a reasonable indicator of habitat characteristics found in the streams. Significance levels for both analyses were Bonferroni adjusted to maintain the experiment-wise error rate with multiple comparisons (Sokal and Rolhf 1995).

A principal component analysis (PCA) was used on the physicochemical habitat parameters collected each month (August 2007 through July 2008) at each site to determine associations among Pfankuch scores, water quality measurements, and physical habitat parameters. Ordination allowed multiple habitat parameters to be converted to a single score, and overall scores to be compared between streams to determine gradients of physical habitat. I used Horn's test to determine the number of relevant PCA components to retain (Horn 1965). To generate site PC scores, the original PCs were varimax rotated to enhance interpretability, and site scores were derived by solving the PC linear combination with raw data measurements from each site. My primary interest with these analyses was to evaluate a gradient of stability based on how the PSI co-varied with physicochemical parameters in a PCA analysis, similar to the analyses presented by Death (1994). However, Death (1994) only compared macroinvertebrate community composition to the principal component (PC) exhibiting the highest correlations with the PSI. In this study, I included multiple PCs in the analysis to determine other habitat gradients that might have affected LPT abundances in these southeastern Louisiana stream systems.

I used a multivariate analysis of variance (MANOVA) to relate site PC scores from September and May to the abundance of the top 95% of collected macroinvertebrate LPTs (by number) from each sampling period. Additionally, common macroinvertebrate community estimates (diversity, evenness, abundance, % EPT, and genera number) were analyzed with six individual analyses of variance (ANOVA). These analyses were performed to determine the effects of stream habitat characteristics, specifically the PSI, on benthic macroinvertebrate community structure.

Results

Habitat

Water quality

Most of the physicochemical variables exhibited little variation in mean values or standard errors among the study sites, including temperature (range: 18 to 20^{o}C), specific conductance ($\leq$0.04 µmhos/cm differences among sites), pH (range: 6-7), and DO (average standard error < 0.11; Table 1). The highest turbidities (> 9.00 NTUs) were found at LAW2 and LAW3, with mean values < 5.0 NTUs recorded at BLUSA2 and BLUSA3. Total carbon was highest in LAW1 (9.23 mg/l) but was below 7 mg/l at PUSH1 and PUSH2. Total nitrogen and organic matter tended to decrease from upstream to downstream sites, particularly organic matter (e.g., PUSH1 to PUSH3). BOD was highest at LAW2 (4.68) and PUSH3 (4.72) and appeared to be considerably higher than in Bogue Lusa Creek. Mean chlorophyll *a* values varied substantially among sites, but similar to the pattern for BOD, BLUSA1, BLUSA2 and BLUSA3 generally yielded the lowest levels among the nine sites.

Physical habitat

Slope varied little between study sites, ranging from 0.11 m /100m at PUSH3 to 0.03m /100 m at PUSH2 (Table 2). Sinuosity was greatest at LAW2 and lowest at BLUSA1 and PUSH2. Sites in Bogue Lusa Creek generally exhibited the highest entrenchment ratio (based on bank-full width and bank-full depth), whereas the other sites appeared to be less incised. Wetted width indicated that BLUSA3, LAW3 and PUSH1, PUSH2 and PUSH3 were the largest sites, particularly compared to the upstream sites on Bogue Lusa and Lawrence creeks. All of the study sites averaged less than 1 m in depth, ranging from a mean of 39.73cm (LAW1) to 65.54cm (PUSH2). Mean flow velocity was twice as high at PUSH3 than at any of the other

Table 1: Means (± standard error, below) of water quality variables: temperature (C°), specific conductivity (µmhos/cm), dissolved oxygen (mg/l), turbidity (NTUs), total carbon (mg/l), total nitrogen (mg/l), organic matter (g), BOD, chlorophyll a (µg/l) and pH collected monthly from August, 2007 to July, 2008 from BLUSA1, BLUSA2 , BLUSA3, LAW1, LAW2, LAW3, PUSH1 , PUSH2, and PUSH3 in Washington Parish, Louisiana.

	BLUSA1	BLUSA2	BLUSA3	LAW1	LAW2	LAW3	PUSH1	PUSH2	PUSH3
Temperature	18.45	18.77	18.87	18.38	18.11	19.29	18.06	18.56	20.07
	±0.52	±0.47	±0.52	±0.53	±0.53	±0.57	±0.42	±0.46	±0.56
Specific Cond	0.02	0.02	0.03	0.04	0.03	0.04	0.06	0.05	0.05
	±3.9e^{-4}	±2.9 e^{-4}	±2.9 e^{-4}	±7.7 e^{-4}	±4.8 e^{-4}	±5.7 e^{-4}	±4.8 e^{-4}	±3.8 e^{-4}	±2.8 e^{-4}
DO	8.66	8.88	8.97	8.49	9.43	9.7	8.57	9.32	9.61
	±0.11	±0.09	±0.1	±0.15	±0.11	±0.08	±0.18	±0.1	±0.13
Turbidity	7.6	4.42	4.96	9.27	9.43	6.13	7.13	6.91	6.71
	±0.73	±0.26	±0.26	±0.38	±0.77	±0.46	±0.37	±0.27	±0.49
Total Carbon	8.31	7.35	7.73	9.23	7.82	8.31	6.45	6.72	7.17
	±0.2	±0.16	±0.26	±0.27	±0.25	±0.24	±0.22	±0.23	±0.28
Total Nitrogen	0.52	0.48	0.45	0.71	0.68	0.69	0.7	0.73	0.66
	±0.05	±0.05	±0.05	±0.05	±0.05	±0.05	±0.06	±0.05	±0.05
Organic Matter	1.46	0.98	0.84	1.53	1.48	0.57	1.29	0.92	0.47
	±0.06	±0.1	±0.07	±0.08	±0.07	±0.05	±0.08	±0.1	±0.02
BOD	1.82	2.02	2.09	4.68	3.94	3.59	3.78	4.02	4.72
	±0.11	±0.11	±0.08	±0.19	±0.17	±0.19	±0.19	±0.2	±0.17
Chlorophyll a	0.9	1.1	1	1.57	1.35	4.23	2.22	2.0	3.68
	±0.08	±0.07	±0.08	±0.23	±0.12	±0.38	±0.14	±0.13	±0.23
pH	6.17	6.22	6.34	6.65	6.61	6.46	6.42	6.58	6.54
	±0.05	±0.05	±0.05	±0.05	±0.04	±0.05	±0.05	±0.05	±0.05

sites. The PSI separated sites into two groups based on PC scores over 55 (less stable; BLUSA1, BLUSA2 and BLUSA3, LAW1 and LAW2, and PUSH1) and under 50 (more stable; LAW3, PUSH2 and PUSH3). Wood surface area and the number of pieces of wood were generally highest at sites with the greatest percent overstory cover. Pebble diameter was highest at PUSH3 (16.94mm) and lowest at PUSH1 (8.34mm). As would be expected, percent coarse substrate was generally highest at sites with greater pebble densities, and % sand substrate showed an inverse relationship to pebble number.

Regression analysis, Time and Pfankuch Stability Index

Results of the multiple regression analysis revealed no overlap between variables that were related to time (monthly sampling periods) and those that were related to the PSI (Table 3). Overall, four variables were related to time and 13 to the PSI (Table 2), with no relationships exhibited by BOD, pH, turbidity, depth, and percent fine substrate.

<u>Habitat and Water quality Principal Components Analysis (PCA)</u>

Horn’s test revealed that the first five PCs best explained the patterns exhibited by the physicochemical variables (62.18% of the variance; Table 4). Examination of variable correlations within each PC indicated that the first PC (PC1) was related to stability and fluvial-derived morphology and contrasted sites that were characterized as being more stable and comprised of coarser substrates, greater pebble densities, higher slopes, greater flow, and straighter channels with less stable sites characterized by greater overstory cover, higher proportions of sand substrates, and higher Pfankuch indices. I interpreted PC2 as an index of stream habitat, as it distinguished sites that were shallower and narrower with high levels of overstory cover and woody debris to deeper, wider sites with little debris habitat. The third PC

Table 2: Means (± standard error below) of habitat variables: slope, wetted width (m), sinuosity, overstory, entrenchment, depth (m), flow (m/sec), wood surface area, wood number, pebble diameter (mm), pebble number, Pfankuch Stability Index, % coarse substrate (g), % sand substrate (g) and % fine substrate (g) collected monthly from August, 2007 to July 2008 from BLUSA1, BLUSA2 , BLUSA3, LAW1, LAW2, LAW3, PUSH1 , PUSH2, and PUSH3 in Washington Parish, Louisiana.

	BLUSA1	BLUSA2	BLUSA3	LAW1	LAW2	LAW3	PUSH1	PUSH2	PUSH3
Slope	0.09	0.05	0.08	0.06	0.04	0.06	0.04	0.03	0.11
Sinuosity	96	65	85	76	43	82	65	96	88
Entrenchment	0.46	0.36	0.26	0.28	0.07	0.16	0.22	0.17	0.16
Wetted Width	5.35	7.89	9.70	5.96	8.81	10.90	11.52	13.99	10.62
	±0.051	±0.05	±0.06	±0.05	±0.06	±0.11	±0.05	±0.06	±0.09
Depth	44.08	57.81	57.13	39.73	58.25	47.30	51.06	65.54	50.38
	±0.95	±0.88	±1.03	±0.54	±0.88	±0.73	±0.47	±0.71	±0.73
Flow	0.13	0.13	0.20	0.11	0.16	0.26	0.23	0.24	0.52
	±0.006	±0.005	±0.006	±0.002	±0.003	±0.008	±0.004	±0.003	±0.004
PSI	61.37	66.12	57.75	62.34	64.75	46.44	60.76	48.73	47.55
	±0.4	±0.46	±0.25	±0.54	±0.56	±0.3	±0.42	±0.27	±0.32
% Overstory	79	79	66	77	79	27	72	36	37
	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01
Wood Surface Area	8.70	5.03	4.10	10.78	6.53	1.59	2.70	2.34	2.37
	±0.18	±0.19	±0.09	±0.23	±0.1	±0.05	±0.04	±0.17	±0.07
Wood Number	9.18	7.59	11.41	16.50	14.18	5.03	9.03	5.58	5.72
	±0.3	±0.25	±0.42	±0.67	±0.33	±0.22	±0.19	±0.18	±0.16
Pebble Diameter	10.83	11.13	10.63	11.20	9.83	15.65	8.34	11.69	16.94
	±0.43	±0.62	±0.75	±0.67	±0.58	±0.46	±0.44	±0.41	±0.31
Pebble Number	15.83	14.50	24.25	12.33	4.67	63.00	11.25	25.75	74.08
	±0.7	±1.12	±1.17	±0.9	±0.41	±1.34	±0.81	±1.14	±1.23

Table 2. Continued.

% Coarse Substrate	14.80 ±1.00	13.14 ±1.02	21.92 ±1.64	6.46 ±0.53	9.43 ±0.99	48.26 ±1.55	5.68 ±0.72	13.51 ±0.85	40.61 ±1.57
% Sand Substrate	78.82 ±1.23	82.47 ±1.00	74.68 ±1.8	90.42 ±0.73	85.86 ±1.13	48.77 ±1.55	87.86 ±1.13	82.95 ±1.12	54.42 ±1.76
% Fine Substrate	6.38 ±0.90	4.39 ±0.78	3.39 ±0.43	3.12 ±0.48	4.71 ±0.75	3.12 ±0.19	6.46 ±0.9	3.54 ±0.46	4.97 ±0.47

Table 3: Relationships of 25 physicochemical parameters to the Pfankuch Stability index (PSI) and time (including squared and cubed terms) as determined with regression analysis. Data presented are P-values for each of the variables, with a Bonferroni-adjusted significance level of a = 0.002.

	PSI	Time	$Time^2$	$Time^3$
Temperature	-	<0.0001	<0.0001	<0.0001
Specific Conductivity	<0.0001	-	-	-
Dissolved Oxygen	-	0.0006	0.007	-
pH	-	-	-	-
Turbidity	-	-	-	-
Total Carbon	-	0.002	-	-
Total Nitrogen	-	<0.0001	<.00001	<0.0001
BOD	-	-	-	-
Organic Matter	0.0009	-	-	-
Chlorophyll a	<0.0001	-	-	-
Slope	-	-	-	-
Wetted Width	<0.0001	-	-	-
Sinuosity	<0.0001	-	-	-
% Overstory	<0.0001	-	-	-
Entrenchment	<0.0001	-	-	-
Depth	-	-	-	-
Flow	<0.0001	-	-	-
Wood Surface Area	<0.0001	-	-	-
Wood Number	<0.0001	-	-	-
Pebble Diameter	-	-	-	-
Pebble Number	<0.0001	-	-	-
PSI	-	-	-	-
% Coarse Substrate	<0.0001	-	-	-
% Sand Substrate	<0.0001	-	-	-
% Fine Substrate	-	-	-	-

described differences in water quality, entrenchment, and biological activity among sites, which I interpreted as a microbial activity component, as values for both pH and specific conductance were well within the tolerable range for macroinvertebrates and likely had no effect on the macroinvertebrate communities at my study sites (Winterbourn and Collier 1987; DeWalt 1997). It appeared that PC4 reflected run off into the streams, and contrasted sites based on differences in total carbon, turbidity, and temperature. Stream temperature and DO levels were highly (inversely) correlated with PC5, but neither parameter appeared to vary sufficiently enough to exert any influence on the macroinvertebrate communities in my study streams. As a consequence, I did not incorporate PC5 in any of the macroinvertebrate-based analyses.

Bivariate plots of site scores revealed both within-site (across months) and between-site variability for the four PCs (Figures 2,3). Almost all of the sites exhibited similar levels of variability among months along PC1 and PC2 (evidenced by the spread of scores for each site on the two axes), although some sites varied more through time along PC1 (e.g., PUSH3), whereas others were more variable along PC2 (e.g., PUSH2; Figure 2). Differences in stability and fluvial morphology among sites were evident along PC1, with sites falling between PUSH3 (higher stability, more open, coarser substrates) and LAW2 (less stable, greater overstory cover, and greater percentages of sandy substrates). Along PC2, sites ranged between LAW1 (smaller stream, high overstory cover and woody debris abundance) and PUSH2 (larger, deeper, more open canopy).

There was no consistent pattern in site score changes from the September and May samples (used later in the analyses of macroinvertebrate/habitat associations) among the sites, i.e., some sites exhibited changes along PC1 (e.g., BLUSA1), whereas others moved along PC2 (e.g., PUSH3). With the possible exceptions of BLUSA3 and LAW3, there did not seem to be

Table 4: Factor loadings of a Principal Components Analysis based on 25 physicochemical variables collected monthly from August, 2007 to July 2008 at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana, along with the Percent variance explained by each principal component. Highlighted and (*) values in each PC indicate variables with correlations greater than 0.50.

	PC1		PC2		PC3		PC4		PC5	
% Variance Explained	26.2		12.9		10.0		6.8		6.2	
Pebble Number	**81**	*	-19		19		-12		12	
% Coarse Substrate (g)	**75**	*	-8		4		-30		21	
Slope	**73**	*	34		-21		12		-7	
Sinuosity	**69**	*	-18		-24		15		-40	
Flow (m/sec)	**57**	*	-42		31		22		10	
% Overstory	**-60**	*	**59**	*	-26		-16		-18	
PSI	**-64**	*	47		-31		-8		1	
% Sand Substrate (g)	**-75**	*	6		-2		34		-25	
Wood Surface Area	-27		**81**	*	-11		24		-10	
Wood Number	-41		**63**	*	16		-2		6	
Depth (m)	-27		**-71**	*	-11		30		19	
Wetted Width (m)	7		**-88**	*	34		-11		7	
Specific Conductivity (µmhos/cm)	0		-37		**73**	*	16		-15	
BOD	7		3		**67**	*	21		7	
pH	5		10		**62**	*	-17		-22	
Entrenchment	9		38		**-69**	*	14		-36	
Total Carbon (mg/l)	4		7		-4		**71**	*	5	
Turbidity (NTUs)	-11		-3		21		**68**	*	13	
Dissolved Oxygen	21		-17		-2		15		**78**	*
Temperature (^{o}C)	5		16		23		**-54**	*	**-60**	*
Pebble Diameter	31		-6		-16		7		24	
Chlorophyll a	22		-4		30		-27		-6	
Organic Matter (g)	-21		19		-1		-2		8	
% Fine Substrate (g)	9		6		-3		-17		16	
Total Nitrogen (mg/l)	-8		-10		9		4		-36	

substantial changes in physicochemical characteristics between the two seasons for most of the study sites.

Although monthly within-site differences in biological activity were much more evident along PC3 (evidenced by the greater spread of site scores relative to PC1 and PC2), differences among streams were also evident, i.e., Lawrence and Pushepetapa creek sites generally exhibited higher scores, with lower scores for the Bogue Lusa Creek sites (Figure 3). Both BLUSA1 and LAW1 exhibited higher scores along PC3 for May relative to September, but for most of the other sites there were no trends in site scores along the two axes between the two months. There were few discernable differences among sites along PC4, with almost all sites exhibiting positive and negative scores and considerable within-site variability in temperature, total carbon, and turbidity during the year. Site scores for PC4 in September and May generally clustered between -1 and zero for all sites except LAW1.

Macroinvertebrates

Wood and sediment samples

I collected 32,166 benthic macroinvertebrates representing nine orders during the September and May sampling periods. Of the macroinvertebrates sampled, 29,689 (92.3%) were collected from woody debris and 2,477 (7.7%) were recovered from sediment samples (Table 5). Colepoterans and dipterans made up 78% of the number organisms collected from wood samples, with tricopterans accounting for an additional 19%. In sediment samples, dipterans comprised 84% of the total number of infaunal invertebrates collected.

Of the 37 macroinvertebrate families that were collected in September 2007 and May 2008, 15 were unique to wood samples (Table 6). Elmid beetles, chironomids and hydropsychid caddisflies comprised 90% by number of xylophilic macroinvertebrates. Sediment samples yielded a total of 22 families, with only burrowing mayflies in the family Ephemeridae being unique to the benthos.

I identified 63 LPTs from the organisms collected during the study, which included 56 genera, 4 subfamilies (the dipterans Chironominae, Tanypodinae, Orthocladiinae and

Prodiamesinae), and 3 families (Baetidae, Tipulidae and Sialidae). Wood samples included 59 LPTs, of which Chironominae, *Macronychus* spp., *Stenelmis* spp., *Hydropsyche* spp., and *Ancyronyx* spp. accounted for 79% of total abundance of xylophilic organisms (Table 7). Sediment samples included 32 LPTs, with Chironominae accounting for 79% of the total abundance if sediment-dwelling taxa.

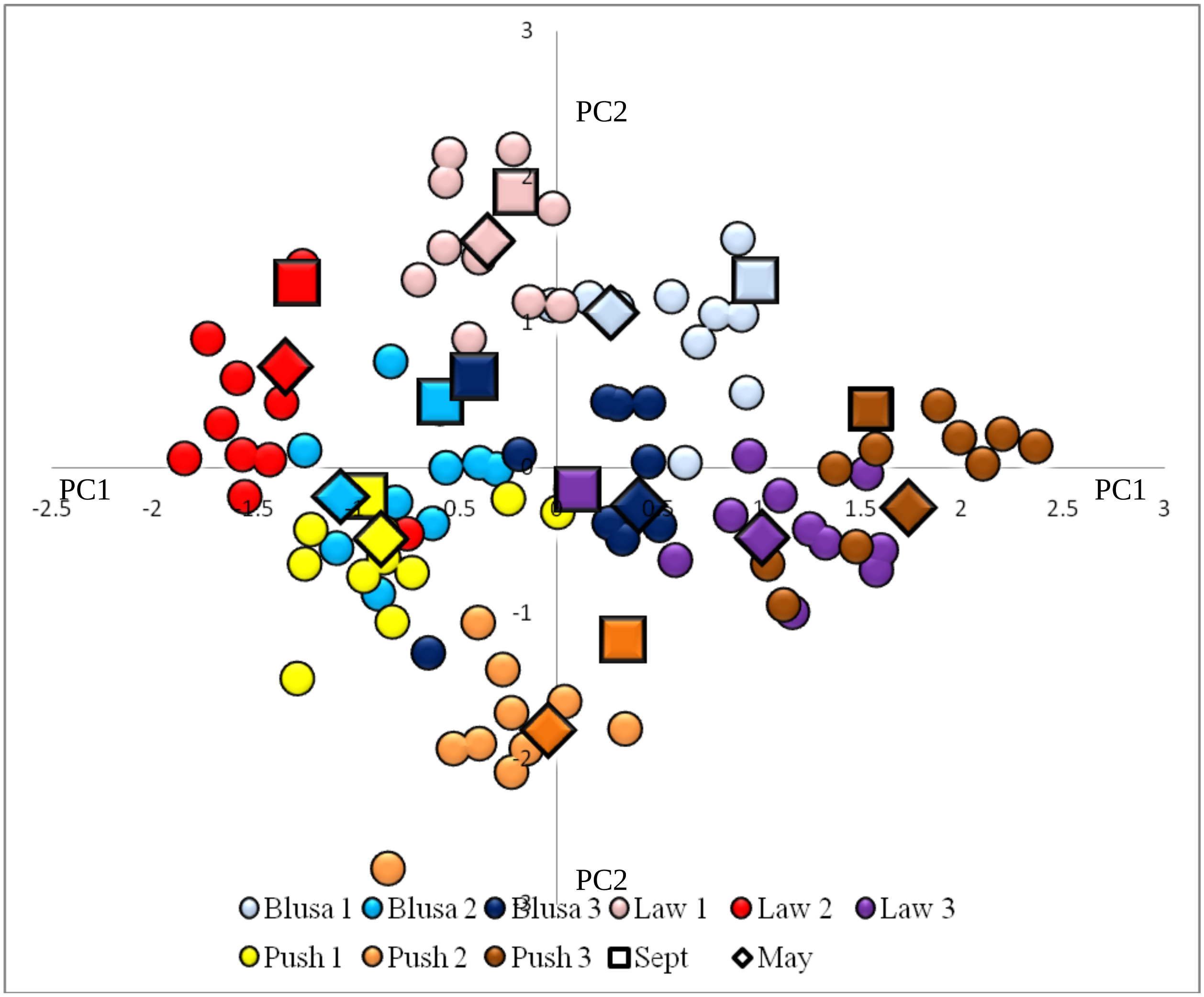

Figure 2: Site scores of PC1 (fluvial morphology/stabilty) and PC2 (woody debris/channel morphology) from the PCA of 25 physicocehemical variable collected monthly from August, 2007 to July 2008 at nine study sites on the Bogue Lusa, Lawrence and Pushepatapa creeks in Washington Parish, Louisiana. September and May symbols indicate scores used in a MANOVA analysis investigating the relationship between physicochemical variables and individual macroinvertebrates and communities.

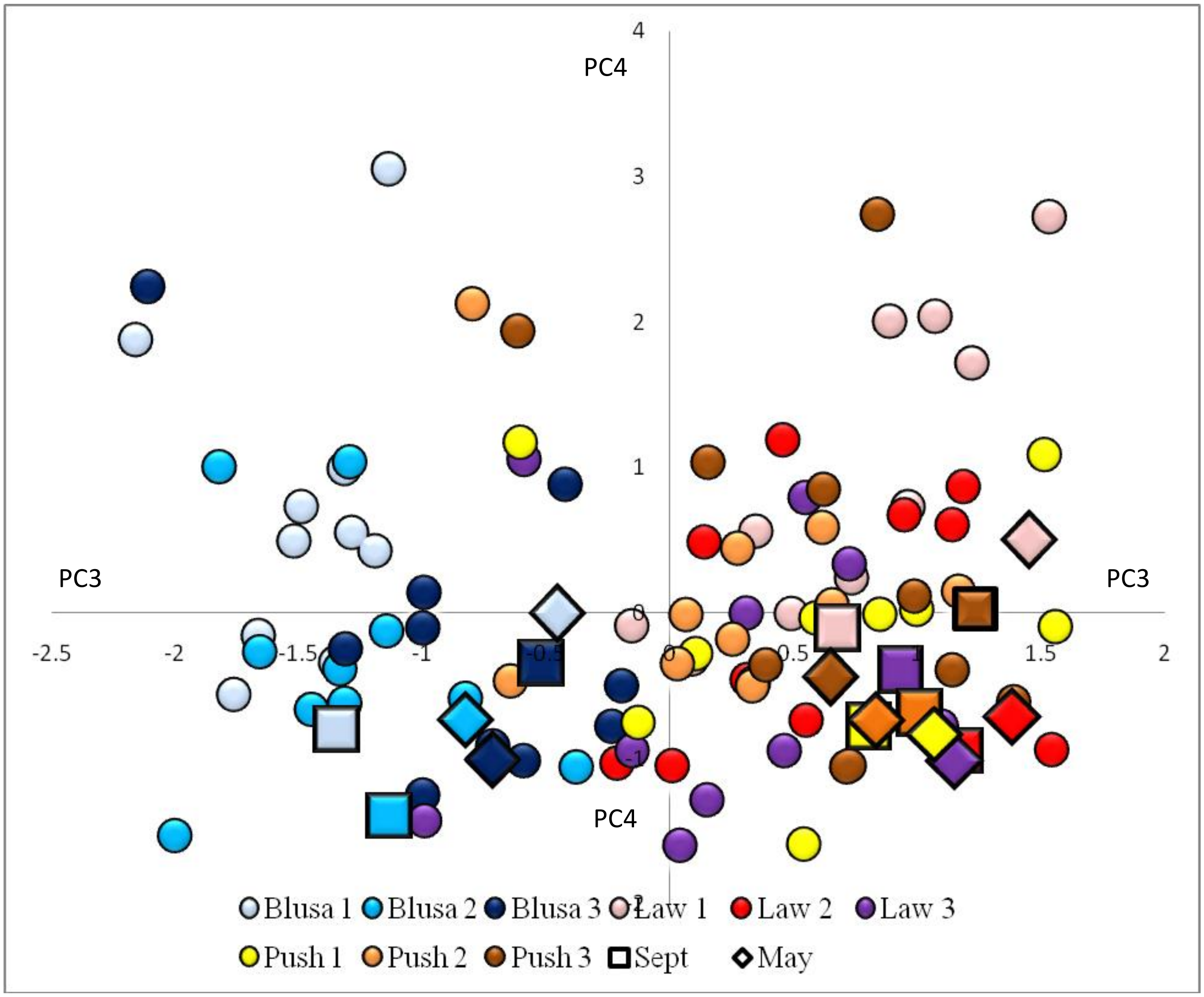

Figure 3: Site scores of PC3 (biological activity/bank morphology) and PC4 (run off) from the PCA of 25 physicocehemical variable collected monthly from August, 2007 to July 2008 at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana. September and May symbols indicate scores used in a MANOVA analysis investigating the relationship between physicochemical variables and individual macroinvertebrates and communities.

Table 5: Total abundance and density (abundance/l volume) of benthic macroinvertebrate orders collected in September, 2007 and May, 2008 from woody debris and substrate sample at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana; (-) indicate values that were not calculated

Substrate	Order	Abundance	Density
Wood	Coleoptera	12,732	4,867.4
	Diptera	10,434	4,298.9
	Trichoptera	5,604	2,177.6
	Ephemeroptera	661	255.8
	Plecoptera	141	53.5
	Hemiptera	57	30.6
	Odonata	51	19.6
	Megaloptera	9	2.8
Total		29,689	11,706.2
Sediment	Diptera	2,081	4,162
	Coleoptera	171	342
	Tricoptera	122	244
	Ephemeroptera	71	142
	Odonata	19	38
	Hemiptera	8	16
	Plecoptera	4	8
	Megaloptera	1	2
Total		2,477	4,954
Grand Total		32,166	16,660.2

Table 6: Density (abundance/l volume) of benthic macroinvertebrate families collected in September, 2007 and May, 2008 from woody debris and substrate sample at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana, (-) indicates organism not present in the sample or values that were not calculated.

	Wood	Sediment
Family	Density	Density
Elmidae	4,824.1	342
Chironomidae	4,002.1	4,088
Hydropsychidae	1,715.7	32
Philopotamidae	203.0	4
Simulidae	208.5	-
Heptageniidae	106.0	12
Hydroptilidae	102.5	30
Polycentropidae	108.3	2
Leptohyphidae	79.9	76
Tipulidae	55.2	24
Baetidae	64.1	14
Perlidae	51.4	6
Leptoceridae	20.3	14
Sialidae	29.7	16
Gyrinidae	10.9	-
Hydrophilidae	13.9	-
Coangrionidae	10.3	-
Psephenidae	11.6	-
Hydeaenidae	6.4	-
Aeshinidae	3.8	2
Corydalidae	2.8	2
Bachycetridae	3.3	-
Glossosomatidae	2.9	14
Macromiidae	1.0	2

Table 6. Continued.

Ameltidae	0.4	-
Cordulidae	0.6	-
Gomphidae	0.7	34
Calopterygidae	0.3	-
Dipseudopsidae	0.4	146
Ephemerellidae	0.9	6
Isonychiidae	0.5	-
Leuctridae	0.6	-
Molonidae	0.6	-
Perlodidae	0.4	-
Veliidae	0.4	-
Ephemeridae	-	26
Total	11,678.2	4,942

Table 7: Density (abundance/l wood volume) of benthic macroinvertebrate genera collected in September, 2007 and May, 2008 from woody debris and substrate sample at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana, (-) indicates organism not present in the sample or values that were not calculated.

	Wood	Sediment
Genus	Density	Density
Chironominae	3,672.4	3,882
Macronychus spp. larvae	2,542.6	34
Stenelmis spp. larvae	1,154.5	220
Hydropsyche spp.	1,206.4	30
Ancyronyx spp. larvae	478.1	4
Macrostenum spp.	443.5	2
Stenelmis spp. adult	307.5	18
Tanypodinae	245.8	196
Wormaldia spp.	152.0	4
Macronychus spp. adult	172.5	-
Stenonema spp.	97.1	8
Ancyronyx spp. adult	131.3	-
Nyctiophylax spp.	94.2	-
Cheumatopsyche spp.	55.2	-
Ochrotrichia spp.	67.1	14
Asioplax spp.	64.5	74
Tipulidae	55.2	24
Baetidae	64.1	14
Orthocladiinae	48.0	-
Perlesta spp.	47.8	-
Chimerra spp.	45.5	-
Oxyethera spp.	26.5	16
Setodea spp.	19.3	14
Sialidae	29.7	16
Dineutus spp.	10.3	-
Brosus spp.	12.8	-
Ectopria spp.	11.4	-
Dubriphia spp. larvae	11.3	62
Prodiamesinae	9.9	-
Dubriphia spp. adults	4.0	2
Genielmis spp.	6.4	-
Neuroclipsis spp.	9.4	2
Hydreana spp.	6.4	-

Table 7. Continued.

Allenhypes spp.	6.9	2
Nehalenna spp.	3.7	-
Brachycentrus spp.	3.3	-
Ceratopsyche spp.	2.9	-
Corydalus spp.	1.9	2
Polycentropodidae spp.	2.8	-
Aeshna spp.	2.0	-
Neoperla spp.	2.1	6
Glossoma spp.	2.4	14
Boyera spp.	0.9	2
Leucrocuta spp.	1.1	-
Macromia spp.	1.0	2
Nigronia spp.	0.8	-
Telabasis spp.	0.3	-
Ameltletus spp.	0.4	-
Gomphus spp.	0.7	26
Gyretes spp.	0.6	-
Oecetis spp.	0.9	-
Anisoptera	0.5	-
Argia spp.	0.4	-
Coryphaeschna spp.	0.7	-
Heptagenia spp.	0.4	-
Hetaerina spp.	0.3	-
Homoptera spp.	0.5	-
Isonychia spp.	0.5	-
Microcylloepus spp. larvae	0.5	-
Molanna spp.	0.6	-
Phylocentropus sp.	0.4	146
Rhagovelia spp.	0.4	-
Ephemerella spp.	-	2
Hagenius spp.	-	2
Hexagenia spp.	-	26
Progomphus spp.	-	6
Total	11,375.5	4,886

September and May samples

Total abundance and density of macroinvertebrates were both higher in September wood samples (16,273.0 organisms, 7.64 organisms/cc of wood) than in May (12,611.0 organisms, 3.73 organisms/cc of wood). September samples yielded 43 LPTs, including 14 LPTs that were not collected in May (Table 8), whereas May samples yielded 32 LPTs, including three LPTs that were not sampled in September. Abundance and density estimates for most LPTs generally decreased from September to May, with the exceptions of Chironominae, *Hydropsyche* spp., *Wormaldia* spp., *Ochrotrichia* spp., Tipulidae, *Setodea* spp., *Cheumatopsyche* spp., and Orthocladiinae.

Abundance patterns of macroinvertebrates recovered from sediment samples were similar to those exhibited by xylophilic LPTs, with decreases from September to May (Table 9). September samples yielded 19 LPTs, including five that were not sampled in May, whereas May samples included 17 LPTS, two of which were not sampled in September.

<u>Relationships Between Benthic Macroinvertebrates and Habitat PC scores</u>

Abundance

Each PC was found to be significant in the overall model of macroinvertebrate abundance in both the September and May wood samples (Table 10). In September, abundances of 14 LPTs were found to be significantly related to the PCs. Abundances of six LPTs were related positively to PC1, whereas eight LPTs were related PC2, seven positively and one negatively. Analyses also revealed positive abundance relationships with PC3 (8 LPTs), and negative relationships with PC4 (7 LPTs). *Chimarra* spp. exhibited a relationship to PC2, PC3, and PC4 that was described by a slope estimate with a different trajectory than other LPTs. Additionally, *Chimarra* spp and *Nyctiophylax* spp. were found to be sensitive to all PCs, and Chironominae, *Macrostenum* spp., *Oxyethira* spp., and Prodiamesinae were sensitive to three of the four PCs.

Table 8: Total abundance and density (abundance/l wood volume) and of benthic macroinvertebrate genera collected in September, 2007 and May, 2008 from woody debris at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana, (-) indicates organism not present in the sample or values that were not calculated, organism that were only found in one sample were excluded from the table.

Wood	Fall		Spring	
Genus	Abundance	Density	Abund ance	Density
Macronychus spp. larvae	4,367	1,973.3	2,096	569.3
Chironominae	4,116	2,238.7	4,677	1,433.8
Stenelmis spp. larvae	2,281	920.5	1,041	234.0
Hydropsyche spp.	975	491.1	2,057	715.3
Ancyronyx spp. larvae	957	401.1	293	77.0
Macrostenum spp.	897	418.4	93	25.2
Stenelmis spp. adults	547	240.6	257	66.8
Tanypodinae	328	139.4	350	106.3
Macronychus spp adults.	302	136.8	126	35.8
Ancyronyx spp.adults	218	123.5	35	7.8
Nyctiophylax spp.	172	70.3	78	23.9
Asioplax spp.	137	53.3	30	11.2
Wormaldia spp.	121	51.6	380	100.5
Stenonema spp.	117	49.2	165	47.9
Chimerra spp.	100	40.2	21	5.2
Baetidae spp.	82	42.0	60	22.1
Oxyethera spp.	61	26.3	1	0.2
Sialidae	54	29.3	1	0.3
Perlesta spp.	53	27.5	75	20.2
Ochrotrichia spp.	45	19.9	157	47.2
Tipulidae	28	12.7	116	42.6
Dubriphia spp. larvae	25	11.3	-	-
Ectopria spp.	24	10.6	3	0.7
Prodiamesinae spp.	24	9.9	-	-
Brosus spp.	23	11.3	6	1.5
Genielmis spp.	18	6.4	-	-
Neuroclipsis spp.	17	9.4	-	-
Hydreana spp.	16	6.4	-	-
Setodea spp.	15	5.8	45	13.5

Table 8. Continued

Nehalenna spp.	12	3.7	-	-
Allenhypes spp.	7	4.8	6	2.1
Brachycentrus spp.	7	3.0	1	0.3
Ceratopsyche spp.	6	2.9	-	-
Corydalus spp.	6	1.9	-	-
Polycentropus spp.	6	2.8	-	-
Dubriphia spp. adults	4	1.8	17	2.3
Glossoma spp.	4	2.4	-	-
Leucrocuta spp.	3	1.1	-	-
Macromia spp.	3	1.0	-	-
Nigronia spp.	3	0.8	-	-
Aeshna spp.	2	0.8	3	1.2
Boyera spp.	2	0.8	1	0.1
Cheumatopsyche spp.	2	1.3	244	53.9
Gomphus spp.	2	0.7	-	-
Orthocladiinae	2	0.7	130	47.3
Gyretes spp.	1	0.5	1	0.2
Ameltletus spp.	-	-	2	0.4
Dineutus spp.	-	-	40	10.3
Telabasis spp.	-	-	3	0.3
Total	16,273	7,642.9	12,611	3,726.7

Table 9: Density (abundance/l wood volume) of benthic macroinvertebrate genera collected in September, 2007 and May, 2008 from sediment substrate at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana, (-) indicates organism not present in the sample or values that were not calculated, organism that were only found in one sample were excluded from the table.

Sediment	Fall	Spring
Genus	Density	Density
Chironominae	2,092	1,790
Stenelmis spp. larvae	188	32
Phylocentropus spp.	120	26
Tanypodinae	96	100
Asioplax spp.	72	2
Dubriphia spp. larvae	54	8
Hexagenia spp.	26	-
Hydropsyche spp.	24	6
Gomphus spp.	22	4
Stenelmis spp. adults	18	-
Macronychus spp. larvae	16	18
Oxyethera spp.	16	-
Glossoma spp.	14	-
Ochrotrichia spp.	12	2
Setodea spp.	12	2
Tipulidae	12	12
Baetidae	8	6
Stenonema spp.	6	2
Ancyronyx spp. larvae	4	-
Wormaldia spp.	2	2
Progomphus spp.	-	-
Sialidae	-	-
Total	2,870	2,034

In the May wood sample, PC scores were related to the abundances of 10 LPTs, six of which were unique to May's wood samples (Baetidae, *Hydropsyche* spp., *Stenelmis* spp. adult, *Stenelmis* spp. larvae, Tipulidae, *Wormaldia* spp.). Significant abundance relationships were found for PC1 (7 LPTs, 4 positive and 3 negative), PC2 (5 LPTs, all negative), PC3 (5 LPTs, 4 positive and 1 negative), and PC4 (4 LPTs, all positive). Among the individual LPTs collected in May, tipulid abundance was related to all of the PCs, whereas the abundance of *Hydropsyche* spp. was related to all of the PCs except PC3.

In the September sediment samples, only PC1 was found to be significant in the overall model of macroinvertebrate abundance, whereas in May, significant invertebrate-habitat relationships were found for PC1, PC2, and PC3. In both months, Chironominae and *Stenelmis* spp. were the only individual LPTs that exhibited significant abundance relationships with the PCs. In September, abundances of both Chironominae and *Stenelmis* spp. larvae were positively associated with PC1. In May, Chironominae abundance was negatively associated with PC2 and *Stenelmis* spp. larval abundance was negatively associated with PC1 and PC3.

Benthic Macroinvertebrate Assemblage

Results of the ANOVAs on September's epixylic macroinvertebrate assemblage estimates revealed significant positive relationships between PC1 and macroinvertebrate diversity, abundance and genera number, but not %EPT (Table 11). Abundance was positively associated with PC1, PC2, and PC3, and negatively associated with PC4. In contrast, community estimates from the May woody debris samples were not related to PC1, although total abundance exhibited positive relationships with PC4 and a negative relationship with PC2. In addition, %EPT associated positively with PC3 in May, whereas the number of genera was positively related to PC4 and negatively to PC2 and PC3.

Table 10: Relationship (estimated slopes, below) of principal components 1-5 to the total abundance benthic macroinvertebrates collected in the September 2007 and May 2008 from wood debris and sediment samples at nine study sites on the Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana; (-) indicates no relationship

	Abundance			
Wood	September			
	PC 1	PC 2	PC 3	PC 4
Wilks' Lambda Factor Significance	0.0105	0.0005	0.0008	0.0003
Stenonema spp.	0.0166	-	-	-
	0.50	-	-	-
Perlesta spp.	0.0441	-	-	-
	0.43	-	-	-
Tanypodinae	0.0282	0.0111	-	0.0343
	1.08	1.58	-	-4.31
Chironominae	0.0123	-	0.0065	0.0087
	15.86	-	27.59	-69.10
Chimarra spp.	0.0394	0.0488	0.0213	0.023
	0.36	-0.43	-0.64	1.65
Nyctiophylax spp.	0.0173	0.019	0.0247	0.0032
	0.57	0.70	0.85	-2.94
Ancyronyx spp.	-	0.0038	-	-
	-	3.70	-	-
Asioplax spp.	-	0.0226	-	-
	-	1.11	-	-
Macrostenum spp.	-	0.0219	0.0002	0.0017
	-	6.51	13.87	-29.84
Oxyethira spp.	-	0.0134	0.0003	0.0025
	-	0.63	1.21	-2.58
Prodiamesinae	-	0.0042	0.0018	0.0013
	-	0.26	0.36	-0.97
Berosus spp.	-		0.0142	-
	-		0.35	-
Ochrotrichia spp.	-	-	0.0268	-
	-	-	0.36	-
Macronychus spp.	-	-	0.0006	0.0279
	-	-	20.16	-33.05

Table 10. Continued.

		May		
Wilks' Lambdas Factor Significance	0.0004	<0.0001	<0.0001	0.0003
Baetidae	0.0057	-	-	-
	0.29	-	-	-
Stenelmis spp. larvae	0.0004	-	<0.0001	-
	-1.79	-	-4.85	-
Stenelmis spp. adult	0.0153	-	<0.0001	-
	-0.37	-	-0.91	-
Wormaldia spp.	0.0729	-	0.0018	-
	-0.33	-	0.85	-
Stenonema spp.	0.0251	-	0.0095	0.0489
	0.25	-	-0.42	0.97
Hydropsyche spp.	0.0013	0.0349	-	0.0074
	7.90	-8.94	-	28.79
Tipulidae	<0.0001	0.0005	0.0249	0.0001
	0.64	-0.93	-0.49	2.62
Asioplax spp.	-	0.0059	-	-
	-	-0.33	-	-
Ochrotrichia spp.	-	0.0302	-	-
	-	-0.45	-	-
Chironominae	-	<0.0001	-	<0.0001
	-	-16.21	-	31.81
Sediment		September		
Wilks' Lambda factor significance	0.0055	0.1821	0.3621	0.0516
Chironominae	0.0002	-	-	-
	8.61	-	-	-
Stenelmis spp. larvae	0.0306	-	-	-
	0.86	-	-	-
		May		
Wilks' Lambda Factor Significance	0.0009	<0.0001	0.037	0.1208
Chironominae	-	<0.0001	-	-
	-	-8.50	-	-
Stenelmis spp. larvae	0.0173	-	0.0022	-
	-0.21	-	-0.39	-

Community metrics did not show a relationship to PC3 in the September sediment samples, although significant relationships were evident between abundance, diversity, evenness and one of the other PCs (Table 11). In May, %EPT did not relate to any PCs, whereas at least one of the other metrics was either positively (PC1, and PC4) or negatively (PC2 and PC3) related to stream habitat characteristics

Table 11: Relationship (estimated slopes, below) of PC 1-5 to Total abundance, Diversity, Evenness, % Ephemeroptera, Plecoptera, and Ttichoptera and Number of genera (NOG) of benthic macroinvertebrate communities collected in September, 2007 and May 2008 from wood debris and sediment samples at nine study sites on Bogue Lusa, Lawrence, and Pushepatapa creeks in Washington Parish, Louisiana; (-) indicates no relationship.

	Community			
Wood	September			
	PC 1	PC 2	PC 3	PC 4
Diversity	0.0197	-	-	-
	0.14	-	-	-
Evenness	-	-	-	-
	-	-	-	-
Abundance	0.0003	0.0007	0.0002	<0.0001
	81.91	95.36	134.30	-397.25
% EPT	-	-	-	-
	-	-	-	-
Number of Genera	0.0117	-	-	-
	1.66	-	-	-
	May			
Diversity	-	-	-	-
	-	-	-	-
Evenness	-	-	-	-
	-	-	-	-
Abundance	-	0.0002	-	0.0005
	-	-82.97	-	198.85
% EPT	-	-	0.0142	-
	-	-	0.21	-
Number of Genera	-	0.0025	0.0113	0.0333
	-	-1.76	-1.21	3.08

Table 11. Continued.

Sediment	September			
Diversity	-	-	-	-
	-	-	-	-
Evenness	-	0.0139	-	-
	-	0.17768	-	-
Abundance	<0.0001	-	-	0.0059
	10.79	-	-	-29.95
%EPT	-	-	-	-
	-	-	-	-
Number of Genera	-	-	-	-
	-	-	-	-
	May			
Diversity	-	-	0.0001	-
	-	-	-0.18	-
Evenness	0.0127	-	-	-
	0.114	-	-	-
Abundance	-	<0.0001	0.0042	0.0058
	-	-9.02	-4.02	11.76
% EPT	-	-	-	-
	-	-	-	-
Number of Genera	-	-	<0.0001	0.0173
	-	-	-0.78	1.17

Discussion

<u>Pfankuch Stability Index Relationship to Habitat Parameters</u>

This study assessed multiple streams, each with the potential to be a reference site, that were in close proximity to one another and were affected by similar weather conditions. In a multiple regression analysis the PSI was associated with a variety of habitat variables, indicating that the index accurately reflected stream channel habitat characteristics that are typically associated with abundances of vertebrate and invertebrate organisms. There was no overlap between variables relating to time of sampling and variables relating to the PSI, and many more habitat variables were related to the PSI than to when samples were collected. These results suggest that variations in important habitat characteristics (i.e. pebble number and wood number) did not vary as much seasonally as they varied between streams. Inter-stream variation in habitat characteristics was further illustrated in the PCA, the results of which showed a gradient of stream stability (as described by the PSI) that explained the greatest amount of variance among the study streams. Inspection of PCA plots show clear separation among study streams, indicating that differences in the geomorphic characteristics of streams could accurately distinguish the study sites, even those that were in close proximity to one another.

Regression analysis and PCA identified pebble number, percent coarse substrate, slope, sinuosity, flow overstory cover and percent sand substrate as variables with strong relationships to the PSI. Results indicate that straighter channels with greater slopes, flows and amounts of coarse substrate were more stable (lower PSI values) than streams characterized by greater levels of overstory cover and higher proportions of sand substrate (higher PSI values). These results are consistent with several studies that have related stream stability to habitat variables that were strongly correlated with the PSI in my study (Lane 1955; Hupp 2000; Allan and Castello 2007;

Mazeika et al. 2004). For example, less stable streams with greater proportions of sandy substrates have greater depositional potential (Minshall 1984; Allan and Castello 2007), due to smaller substrates requiring less force to be lifted into the water column and be redistributed (Newbury and Gaboury 1993).

<u>Relationships Between Benthic Macroinvertebrates and Stability</u>

Results of my study showed that variability in channel stability between streams affected macroinvertebrate LPTs and assemblage abundances in both fall and spring, regardless of stream size, stream productivity or microhabitat. Stable sites were characterized by macroinvertebrate assemblages with a greater total abundance, diversity and number of genera. These results are similar to those of other studies done in a diversity of stream systems ranging from lowland Arizona (Fisher et al.1982), to Idaho (Robinson and Minshall 1986), Sweden (Malmqvist and Otto 1987), and New Zealand (Death and Winterbourn1995a).

Further, this study identified macroinvertebrates that were associated with stable sites (i.e. the stonefly *Perlesta* spp., the mayflies Baetidae and *Stenonema* spp., the caddisflies *Chimerra* spp., *Nyctiophylax* spp., and *Hydropsyche* spp., and the true flies Tanypodinae Chironominae) and if present in macroinvertebrate samples may be good indicators of channel stability. *Perlesta* spp., *Stenonema* spp. and Baetidae are all known to prefer gravel-cobble streams (Waltz and Burian 2008; Stewart and Stark 2008), conditions that were found at the most stable study site (PUSH3). *Chimarra* spp. and *Nyctiophylax* spp. are caddisflies in the suborder Annulipalpia, a group of Trichopterans that make fixed retreats (Wiggins and Currie 2008), and their sessile life history strategy may explain their apparent sensitivity to habitat disturbance. Caddisflies in the genus *Hydropsyche* were also more abundant at more stable sites, which was also reported for *Hydropsyche* caddisflies in a Manitoba, Canada stream (Cobb and

Flannagan1990). These organisms are intolerant of anthropogenic disturbances and should be good indicators of quality stream conditions, at least with regards to channel stability and land-use impacts.

In addition to their relationship with the PSI, the dipteran LPTs Tanypodinae and Chironominae also showed abundance relationships with habitat parameters described by PC2, PC3, and PC4. These subfamilies comprise a numerous and diverse group of organisms and are known to be tolerant of a wide variety of habitat conditions (Ferrington et al. 2008). The broad range of habitat associations seen in these midges may be due to specific relationships between certain genera/species and habitat variables, and elucidating these relationships will likely require identification to a lower taxonomic level.

Although the abundance of many macroinvertebrate LPTs were positively associated with stream stability, there were also several organisms that were more abundant at less stable sites (i.e. larval and adult *Stenelmis* spp. and the caddisfly *Wormaldia* spp.). Elmid beetles in the genus *Stenelmis* are sedentary inhabitants of vegetation or woody debris in slower moving waters, and are known to be sensitive to pollution (Brown 1987; White and Roughley 2008). Increased abundances of these organisms may be good indicators of anthropogenic disturbances that are impacting channel stability and sediment composition at less stable sites like BLUSA2 and LAW2.

The PSI has been used extensively to evaluate stream stability and its relationship to resident biotic communities (Rounick and Winterbourn 1982; Death and Winterbourn 1994; Death and Winterbourn1995a; Townsend et al. 1997; Duncan et al. 1999; Robertson and Milner 1999; McIntosh 2000; Gislason et al. 2001; Lods-Crozet 2001a; Lods-Crozet 2001b; Maiolini and Lencioni 2001; Heiber et al 2002). Stream stability is an important factor influencing abundance and richness of benthic macroinvertebrate communities and has been shown to differ along gradients of physically-disturbed streams (Fisher et al. 1982; Robinson and Minshall 1986; Malmqvist and Otto 1987; Death and Winterbourn 1995a). There is strong evidence that the PSI may serve as a cost-effective surrogate to more time-consuming and laborious techniques for assessment of stream habitat characteristics. Because the PSI was closely associated with many commonly-measured habitat variables, the index can provide an easily-interpretable summary assessment of conditions that influence the quality of stream habitats for lotic organisms in southeastern Louisiana streams. The PSI could be a valuable tool for incorporation into continuing efforts to refine stream monitoring programs, allowing a substantial amount of information to be condensed into a meaningful numeric parameter that could then be related to other abiotic and biotic characteristics of interest.

Macroinvertebrates Habitat Associations

Macroinvertebrates Assemblages in Wood and sediment samples

Woody debris consistently yielded far more diverse and abundant macroinvertebrate assemblages than benthic substrates in the study streams, which has also been reported for other stream systems in Louisiana (Drury and Kelso 2000; Kaller and Kelso in press), the southeastern United States (Benke et al. 1984; Smock et al. 1989) and the upper Midwest (Johnson et al. 2003). The most abundant xylophilic organisms were midges (particularly the subfamily Chironominae), riffle beetles and caddisflies. High densities of xylophilic chironomids have been found in other physicochemically-diverse streams (Drury and Kelso 2000; Kaller and Kelso 2006d; Ferrington et al. 2008), and caddisflies have also been reported in high densities in streams with elevated organic inputs (Roback 1974). Interestingly, beetles are typically found in low densities in stream systems (White and Roughley 2008), but the epixylic riffle beetles

Macronychus spp., *Stenelmis* spp., *Ancyronyx* spp., which are known to be sensitive to pollution (Brown 1987; White and Roughley 2008) were relatively abundant in my study streams.

Sediment samples yielded a dipteran-dominated assemblage characterized by low-diversity and low evenness in both sampling months. Densities of substrate-dwelling dipterans in the sub-family Chironominae were more than an order of magnitude higher than other LPTs in most samples. In light of the low abundance of other organisms in sediment samples, interpreting habitat relationships was difficult and probably not meaningful.

Macroinvertebrate Communities in September and May

Differences in the composition and abundance of the macroinvertebrate community in September and May were evident in both the community as a whole and in individual LPTs. Overall, total macroinvertebrate abundance and density were greater in September relative to May, a pattern that was also evident in the density of elmid beetles in both woody debris and sediment samples. DeMarch (1976) documented sediment-related seasonal changes in habitat, with greater spring flows causing more distinct sediment types. It may be that high spring flows in these southeastern Louisiana streams exacerbate differences in substrate composition between stable and unstable streams (Death and Winterbourn 1994; Mazeika et al. 2004), which is reflected in the abundance and species composition of resident macroinvertebrates. This conclusion is supported by the substantial differences in macroinvertebrate habitat associations that were apparent between September and May.

In September, the abundance of 11 LPTs collected from woody debris as well as total assemblage abundance were positively related to (individually or a combination of habitat parameters) narrower channels with abundant woody debris, greater BOD, and higher stream temperatures. Many of these organisms are thought to have collector/gatherer feeding strategies

(*Ancyronyx* Larvae spp., *Macronychus* Larvae spp., Chironominae, Prodiamesinae, *Asioplax* spp. and *Macrostenum* spp.) whereas others (*Brosus* spp., *Ochrotrichia* spp. and *Oxyethera* spp.) are classified as collector gatherers/general herbivores (Merritt et al. 2008). Collector/gatherers consume fine particulate organic matter (FPOM), and these organisms may be taking advantage of more stable flow conditions of the fall in order to occupy less stable habitats like those found in LAW2 and BLUSA2, where warmer temperatures may result in higher leaf breakdown rates and greater BODs (Abelho et al. 2005).

In May, macroinvertebrate LPTs and total assemblage abundance was associated with stream geomorphology, with greater numbers of organisms found in more stable, larger, and more entrenched streams. Abundance was also positively associated with sites that were subject to more runoff and higher DO levels, but this relationship was likely driven by abundances of *Hydropsyche* spp. and Chironominae, the two most abundant organisms in May samples. In addition, diversity and percent EPT were highest at sites with greater levels of BOD. The latter relationship may be related to the collector/gatherer and collector/filterer feeding strategies of mayflies, stoneflies and caddisflies, reflecting a preference for streams that provide higher levels of FPOM and microbial activity.

In both sampling periods I found organisms that were associated with several habitat variables, as well as LPTs that exhibited specific associations with single habitat variables. Consequently, the presence/absence and/or abundance of these organisms may be good indicators of a wide variety of water quality and habitat impacts in these southeastern streams. For example, greater abundances of *Chimarra* spp. and *Nyctiophylax* spp. in streams exhibiting higher scores on all habitat PCs in the fall indicates that these organisms would likely be most abundant in less-degraded streams, reflecting higher stream stability, better water quality, and an abundance of woody debris. Similarly, abundance patterns of *Hydropsyche* spp., Tipulidae, larval *Ancyronyx* spp. and *Asioplax* spp., *Berosus* spp. and *Ochrotrichia* spp. were strongly related to several physicochemical characteristics of the study streams in May. Indicator taxa are commonly used in many monitoring programs and serve as a cost effective tool for monitoring ecosystem changes in chemical, physical and biological parameters (Hilty and Marenlender 2000).

Management Implications

Because of the strong relationships between the PSI, stream habitat characteristics, and stream macroinvertebrate community composition, I believe that the stability index should be an integral part of biotic indices developed to assess low gradient Louisiana streams. Also, stream protection/enhancement programs should focus on minimizing changes to stream characteristics associated with channel stability (i.e. sediment type and bank vegetation). In both multiple regression and PCA analyses, the PSI was positively associated with sediment particle size, slope, sinuosity, flow velocity, and overstory cover. This is strong evidence that the PSI may serve as a cost effective surrogate to more time-consuming and laborious measurements like pebble counts and sediment sieving. Combining the PSI with several other easily measured stream characteristics (slope, sinuosity, flow velocity, overstory cover) would offer a relatively cheap, simple, and quick method to accurately describe stream conditions in this region.

In addition to channel stability and stream physicochemistry, there were other habitat parameters that significantly affected macroinvertebrate abundance and distribution in these study streams. There was a striking difference in macroinvertebrate abundance between woody debris and benthic habitats, with much higher densities and diversities among the epixylic assemblage. Kaller and Kelso (in press) suggest that small woody debris constitutes an extremely important habitat in Louisiana streams, and my study confirmed that accurate descriptions of macroinvertebrate communities in these streams requires collection of woody debris samples. A line transect method should probably also be an integral part of stream habitat monitoring as a simple way to quantify the abundance of biotically-important woody habitat (Wallace and Benke 1984).

Macroinvertebrates in southeastern Louisiana were not found to be abundant or diverse in sediment samples. However, because I found fall/spring differences in benthic macroinvertebrate assemblage composition and habitat associations, further research on seasonal or monthly changes in benthic macroinvertebrates may enhance our understanding of organism sensitivities to different habitat parameters at different times of the year, as well as provide insight into when benthic samples should be collected for monitoring purposes. The metabolic activity of a stream, as evidenced by BOD, was also found to significantly affect the abundance of the benthic macroinvertebrate assemblage in the study streams. A measure of the stream metabolism like BOD may be important to include in a monitoring program in southeastern Louisiana, and future studies should focus on understanding how stream metabolism is related to biotic and abiotic stream characteristics, as well as land use practices. This study also established macroinvertebrate taxa with the potential to be used as indicators of ecosystem health and anthropogenic change. Further evaluation of the usefulness of these organisms is needed, in addition to the development of concrete physicochemical metrics to assess stream quality.

In conclusion, my study indicates that incorporating the PSI, line transects estimates for woody debris, and BOD along with measurement of stream width, depth, flow, slope, sinuosity, and total carbon and nitrogen may be the best approach for understanding natural and anthropogenic impacts on macroinvertebrate communities in southeastern Louisiana streams.

Although assessments of channel stability are typically scaled to the reach level (Townsend 1997), channel stability also likely affects conditions at the microhabitat scale, due to variations in microhabitat being primarily caused by hydrologic and geomorphic stream factors (Sheldon and Walker 1989). Studies looking at multiple spatial scales (microhabitat, reach, stream segment) may also prove to be beneficial in determining additional sensitivities of indicator taxa. Although I found differences in habitat and macroinvertebrate community structure among my study sites, most of these streams are probably indicative of relatively good (least-impacted) habitat conditions in geomorphologically-distinct streams in southeastern Louisiana. Additional work is needed in streams that grade from high quality (i.e. like those in this study) to low quality (streams with greater anthropogenic disturbances) in order to determine biologically sensitive organisms and other physicochemical endpoints for a monitoring program in coastal plain streams.

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Appendix A. Pfankuch Stability Index

UPPER BANKS	EXCELLENT		GOOD		FAIR		POOR	
Landform slope	Bank slope gradient <30%	2	Bank slope gradient 30-40%	4	Bank slope gradient 40-60%	6	Bank slope gradient >60%	8
Mass-wasting (existing or potential)	No evidence of post or any potential for future mass-wasting into channel.	3	Infrequent and/or very small. Mostly healed over. Low future potential.	6	Moderate frequency and size, with some raw spots eroded by water during high flows.	9	Frequent or large, causing sediment OR imminent danger of same.	12
Debris jam potential (floatable objects)	Essentially absent from immediate channel area.	2	Present but mostly small twigs and limbs.	4	Present, volume and size are both increasing,	6	Moderate to heavy amounts, mainly larger sizes.	8
Vegetative bank protection	>90% plant density. Vigor and variety suggests a deep, dense, soil binding root mass.	3	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	6	50-70% density. Lower vigor and species form a somewhat shallow and discontinuous root mass.	9	<50% density plus fewer species and vigor indicate discontinuous and shallow root mass.	12
Channel capacity	Ample for present plus some increases. Peak flows contained. Width to Depth (W/D) ratio <7.	1	Adequate. Overbank flows rare. W/D ratio 8 to 15.	2	Barely contains present peaks. Occasional over-bank floods. W/D ratio 15 to 25.	3	Inadequate. Overbank flows common. W/D ratio >25.	4
LOWER BANKS								
Bank rock content	65% with large, angular boulders 30cm numerous.	2	40 to 65'%, mostly small boulders to cobbles 15-30cm.	4	20 to 401, with most in the 7.5-15cm diameter class.	6	<20% rock fragments of gravel sizes, 2.5-7.5 cm or less.	8
Obstructions (flow deflectors Sediment traps)	Rocks and old logs firmly embedded. Flow pattern without cutting or deposition. Pools and riffles stable.	2	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	4	Moderately frequent, unstable obstructions and deflectors move with high water causing bank cutting and filling of pools.	6	Frequent obstructions and deflectors cause bank erosion. Sediment traps' full channel migration occurring.	8
Undercutting	Little or none evident. Infrequent raw banks <150cm high.	4	Some, intermittently at outcurves and constrictions. Raw banks <30cm.	8	Significant. Cuts 15-30cm high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some >30cm high. Failure of overhangs	16
Deposition	Little or no enlargement of channel or point bars.	4	Some new increase in bar formation, mostly from coarse gravels.	8	Moderate deposition of new gravel and coarse sand on old and some new bars.	12	Extensive deposits of predominantly fine particles. Accelerated	16
STREAM BED								
Rock angularity	Sharp edges and corners, plane surfaces roughened.	1	Rounded corners and edges. Smooth and flat.	2	Corners and edges wel1 rounded in two dimensions.	3	Well rounded in all dimensions.	4
Brightness	Surfaces dull, darkened or stained. Not "bright".	1	Mostly dull, but may have up to 35% bright surfaces.	2	Mixture, 50-50% dull and bright i.e. 35-65%.	3	Predominantly bright, 65%, exposed surfaces.	4
Consolidation or particle packing	Assorted sizes tightly packed and/or overlapping.	2	Moderately packed with some overlapping.	4	Mostly a loose assortment with no apparent overlap.	6	No packing evident. Loose, easily moved.	8
Bottom size distribution & stable	No change in sizes evident. Stable materials 80-100%	4	Distribution shift slight. Stable materials 50-80%.	8	Moderate change in sizes. Stable materials 20-50%	12	Marked change. Stable materials 0-20%	16
Scouring and deposition	<5% of the bottom affected by scouring and deposition.	6	5-30% affected. Scour at constrictions and where steep. Pool deposition.	12	30-50% affected. Deposits and scour at obstructions, constrictions, and bends.	18	> 50% of bed in a state of flux or change nearly year-long.	24
Clinging aquatic vegetation (moss and algae)	Abundant, growth largely moss, dark green, perennial. In swift water too.	1	Common. Algal forms in low velocity and pool areas. Moss and swifter waters.	2	Present but spotty, mostly in backwater areas. Seasonal blooms	3	Perennial types scarce or absent. Yellow-green, short term bloom present.	4
COLUMN TOTALS								

Totals range from 38 (stable) to 152 (unstable)

Appendix B. Total Number of Benthic Macroinvertebrates

Woody debris	BLUSA1	BLUSA2	BLUSA3	LAW1	LAW2	LAW3	PUSH1	PUSH2	PUSH3	Total
Coleoptera										
Ancyronyx spp. Adult	7	67	7	73	15	72	8	3	1	253
Ancyronyx spp. Larvae	253	179	97	246	54	163	128	96	34	1250
Dubriphia spp. Adult	0	0	0	4	0	0	17	0	0	21
Dubriphia spp. Larvae	0	0	10	9	0	1	1	2	2	25
Gonielmis spp.	10	0	3	0	0	0	1	0	4	18
Macronychus spp. Adult	43	50	48	105	57	31	20	47	27	428
Macronychus spp. Larvae	453	386	415	846	621	1095	753	863	1031	6463
Microcylloepus spp. Larvae	0	0	0	1	0	0	0	0	0	1
Stenelmis spp. Adult	108	351	69	206	36	5	2	17	10	804
Stenelmis spp. Larvae	649	1825	422	219	25	46	6	25	105	3322
Dineutus spp.	2	0	2	1	7	4	14	5	5	40
Gyretes spp.	0	0	0	1	0	0	0	1	0	2
Hydraena spp.	0	0	0	16	0	0	0	0	0	16
Brosus spp.	0	5	0	0	0	12	0	0	12	29
Ectopria spp.	1	6	2	0	0	2	3	7	6	27
Diptera										
Chironominae	1047	732	515	823	517	1367	707	1665	1420	8793
Orthocladiinae	0	0	0	2	0	130	0	0	0	132
Prodiamesinae	11	0	0	1	0	12	0	0	0	24
Tanypodinae	209	115	32	80	26	101	23	38	54	678
Culicidae	33	0	2	8	3	25	1	4	0	76
Tipulidae	4	12	0	0	1	8	2	26	91	144

Appendix B. Continued

Ephemeroptera										
Ameletus spp.	0	0	0	0	0	0	0	2	0	2
Baetidae	9	28	13	4	1	12	9	4	62	142
Heptagenia spp.	0	0	1	0	0	0	0	0	0	1
Leucrocuta spp.	0	0	0	0	0	0	0	3	0	3
Stenonema spp.	58	87	19	2	3	6	27	23	57	282
Isonychia spp.	0	0	0	1	0	0	0	0	0	1
Allenhypes spp.	0	0	0	0	0	7	0	0	6	13
Asioplax spp.	1	7	4	3	1	65	7	35	44	167
Hemiptera										
Homoptera	0	0	0	1	0	0	0	0	0	1
Saldidae	0	1	1	0	1	1	0	2	49	55
Rhagovelia spp.	0	0	0	0	1	0	0	0	0	1
Megaloptera										
Corydalus spp.	0	1	0	0	0	2	0	2	1	6
Nigronia spp.	2	1	0	0	0	0	0	0	0	3
Odonata										
Aeshna spp.	2	1	1	0	0	1	0	0	0	5
Argia spp.	0	1	0	0	0	0	0	0	0	1
Boyeria spp.	1	1	0	1	0	0	0	0	0	3
Anisoptera	0	0	0	1	0	0	0	0	0	1
Coryphaeschna spp.	0	0	0	0	1	0	0	0	0	1
Hetaerina spp.	0	0	0	0	0	0	0	1	0	1
Nehalennia spp.	5	0	0	2	0	0	0	5	0	12
Telebasis spp.	0	2	0	0	0	0	1	0	0	3
Gomphus spp.	1	1	0	0	0	0	0	0	0	2
Macromia spp.	2	0	1	0	0	0	0	0	0	3

Appendix B. Continued

Plecoptera										
Neoperla spp.	0	3	0	0	1	0	0	1	0	5
Perlesta spp.	2	36	11	0	0	2	18	4	55	128
Trichoptera										
Brachycentrus spp.	0	0	5	0	0	0	0	1	2	8
Phylocentropus spp.	0	1	0	0	0	0	0	0	0	1
Glossosoma spp.	0	0	0	1	3	0	0	0	0	4
Ceratopsyche spp.	0	0	0	0	6	0	0	0	0	6
Cheumatopsyche spp.	0	2	8	2	0	8	152	28	46	246
Hydropsyche spp.	14	100	93	263	195	417	484	285	1181	3032
Macrostenum spp.	12	83	37	1	7	624	75	9	142	990
Ochtotrichia spp.	14	13	20	0	0	61	9	64	21	202
Oxyethera spp.	0	0	2	2	0	51	0	0	7	62
Oecetis spp.	0	0	0	2	0	0	0	0	0	2
Setodes spp.	12	13	5	0	5	6	7	11	1	60
Molanna spp.	1	0	0	0	0	0	0	0	0	1
Chimerra spp.	13	21	23	3	1	2	2	2	54	121
Wormaldia spp.	32	15	6	165	86	37	92	49	19	501
Neureclipsis spp.	0	0	0	2	10	0	5	0	0	17
Nyctiophylax spp.	42	55	12	19	7	37	3	35	40	250
Polycentropus spp.	0	0	0	6	0	0	0	0	0	6
Total	3053	4201	1886	3122	1691	4413	2577	3365	4589	28897

Appendix B. Continued

Sediment	BLUSA1	BLUSA2	BLUSA3	LAW1	LAW2	LAW3	PUSH1	PUSH2	PUSH3	Total
Coleoptera										
Ancyronyx spp. Larvae	1	0	1	0	0	0	0	0	0	2
Dubriphia spp. Adult	0	0	0	0	0	1	0	0	0	1
Dubriphia spp. Larvae	3	0	9	8	2	2	1	6	0	31
Macronychus spp. Larvae	7	0	1	1	1	1	0	2	4	17
Stenelmis spp. Adult	2	1	0	6	0	0	0	0	0	9
Stenelmis spp. Larvae	52	38	13	4	0	0	1	1	1	110
Diptera										
Chironominae	205	294	122	103	35	238	168	471	305	1941
Tanypodinae	24	33	4	18	1	6	2	1	9	98
Culicidae	13	0	0	4	0	5	1	2	0	25
Tipulidae	4	0	0	0	0	0	0	0	8	12
Ephemeroptera										
Baetidae	0	1	4	1	0	0	1	0	0	7
Hexagenia spp.	1	2	0	1	0	0	0	9	0	13
Ephemerella spp.	0	0	1	0	0	0	0	0	0	1
Stenonema spp.	0	0	1	0	0	2	1	0	0	4
Allenhyphes spp.	0	0	0	0	0	0	1	0	0	1
Asioplax spp.	0	0	1	0	0	18	0	4	14	37
Hemiptera										
Saldidae	0	7	1	0	0	0	0	0	0	8
Megaloptera										
Corydalus spp.	0	0	1	0	0	0	0	0	0	1

Appendix B. Continued

Odonata										
Boyeria spp.	1	0	0	0	0	0	0	0	0	1
Gomphus spp.	0	11	0	1	1	0	0	0	0	13
Hagenius spp.	0	0	1	0	0	0	0	0	0	1
Progomphus spp.	0	1	0	0	0	0	0	0	2	3
Macromia spp.	0	0	0	0	0	1	0	0	0	1
Plecoptera										
Neoperla spp.	1	0	1	0	0	1	0	0	0	3
Trichoptera										
Phylocentropus spp.	28	41	4	0	0	0	0	0	0	73
Glossosoma spp.	0	0	0	0	0	7	0	0	0	7
Hydropsyche spp.	0	0	2	3	0	2	5	0	3	15
Macrostenum spp.	1	0	0	0	0	0	0	0	0	1
Ochtotrichia spp.	1	0	0	0	0	1	0	4	1	7
Oxyethera spp.	0	0	0	0	0	3	0	0	5	8
Setodes	3	1	0	0	0	2	0	0	1	7
Wormaldia spp.	0	0	1	0	0	0	0	0	1	2
Neureclipsis spp.	0	0	0	1	0	0	0	0	0	1
Total	347	430	168	151	40	290	181	500	354	2461

Appendix C. Monthly Habitat Measurements

(standard error below (+/-) for data collected at each transect)

BLUSA1												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	25.3	23.2	16.7	14.2	8.9	11.1	16.2	15.5	20.2	22.5	23.5	24.2
Specific Cond	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02
DO	7.3	9.6	9.3	9.2	10.4	9.5	9.0	9.8	7.8	7.6	7.0	7.4
pH	6.1	6.1	6.1	5.8	6.8	5.2	5.9	6.1	6.2	7.6	6.0	6.0
Turbidity	13.8	3.6	4.7	2.9	5.3	6.5	29.6	7.1	8.1	3.8	2.1	3.7
Slope	0.1	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	96.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.5	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	13.3	9.3	14.8	12.3	11.9	12.3	12.8	14.6	14.9	2.4	1.5	9.8
Pebble Number	11.0	23.0	24.0	16.0	12.0	7.0	26.0	24.0	6.0	8.0	14.0	19.0
% Coarse Substrate	28.4	9.4	15.7	25.6	5.9	8.4	11.7	26.1	1.8	0.7	29.6	14.3
% Sand Substrate	62.5	59.9	71.8	73.0	82.4	91.4	78.5	73.7	98.0	99.1	70.2	85.5
% Fine Substrate	9.2	30.7	12.5	1.4	11.7	0.2	9.8	0.2	0.2	0.2	0.2	0.2
Total Carbon	6.3	6.8	4.2	7.8	10.6	12.5	9.5	9.5	7.5	8.3	8.7	8.1
DOC	4.1	6.3	2.5	6.3	7.5	9.2	8.8	8.5	5.2	7.0	6.2	6.7
Total Nitrogen	2.0	0.6	0.4	0.3	0.3	0.5	0.4	0.4	0.3	0.3	0.3	0.4
BOD	1.2	0.9	1.4	4.9	1.1	1.6	3.2	1.6	1.3	2.0	2.0	1.0
Organic Matter	1.2	2.3	2.1	2.0	1.3	0.7	0.8	2.1	1.1	1.9	1.0	1.0
Chlorophyll a	1.6	1.2	0.4	0.0	0.3	2.5	0.0	1.5	1.1	0.1	0.5	1.6

Apendix C. Continued.

Bank Full Width	8.5	-	-	-	-	-	-	-	-	-	-	-
	0.0	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	4.7	5.4	5.0	4.9	5.2	5.3	6.3	6.4	5.7	5.4	5.3	4.9
	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
% Overstory	0.9	0.9	0.8	0.8	0.6	0.6	0.6	0.7	0.9	1.0	0.8	0.9
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	167.0	-	-	-	-	-	-	-	-	-	-	-
	1.2	-	-	-	-	-	-	-	-	-	-	-
Depth	36.5	38.8	37.9	37.0	39.7	51.5	70.2	52.6	43.3	44.2	41.2	36.0
	0.5	0.6	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.6	0.6	0.6
Flow	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	173.2	52.1	114.6	231.5	88.3	144.5	48.0	103.2	204.0	79.3	89.7	125.1
	8.2	2.1	5.1	13.3	2.3	2.9	1.1	5.5	17.1	1.8	3.7	5.9
Wood SA	9.8	7.5	7.9	11.0	9.2	13.2	6.0	7.6	9.5	8.3	7.8	8.6
	0.3	0.1	0.2	0.3	0.1	0.2	0.1	0.2	0.3	0.1	0.1	0.2
Wood Number	6.2	13.9	7.4	9.4	7.1	12.3	7.3	7.6	16.0	8.4	7.7	6.8
	0.1	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
PSI	63.8	67.1	65.6	59.4	59.1	61.4	57.1	53.2	58.6	64.7	60.6	65.8
	0.2	0.2	0.2	0.3	0.2	0.1	0.3	0.1	0.2	0.3	0.2	0.2

Apendix C. Continued.

	BLUSA2											
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	24.6	24.3	19.1	14.1	10.8	11.6	16.2	16.1	19.5	22.1	23.2	23.8
Specific Cond	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
DO	7.6	9.7	9.9	9.2	10.1	9.4	9.0	9.7	8.9	8.0	7.5	7.7
pH	6.1	6.1	6.1	5.9	6.2	5.1	5.7	6.5	7.0	6.8	6.7	6.4
Turbidity	2.7	1.9	3.5	2.0	5.0	5.2	11.4	7.2	5.3	3.9	1.7	3.2
Slope	0.1	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	65.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.4	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	13.5	10.5	18.0	14.3	11.6	14.9	8.9	9.0	23.6	1.8	1.0	6.3
Pebble Number	10.0	11.0	46.0	7.0	10.0	3.0	19.0	18.0	22.0	2.0	14.0	12.0
% Coarse Substrate	2.9	0.0	27.3	28.3	29.3	11.5	0.8	15.7	14.5	3.5	9.6	14.3
% Sand Substrate	85.5	72.5	65.8	71.6	68.6	88.4	96.1	84.2	85.1	96.2	90.1	85.5
% Fine Substrate	11.6	27.5	6.9	0.2	2.1	0.2	3.1	0.1	0.3	0.3	0.2	0.2
Total Carbon	5.8	5.7	4.0	6.3	9.1	10.0	9.4	7.7	7.5	7.2	7.6	7.9
DOC	4.0	5.0	2.2	4.6	7.5	5.9	8.3	6.1	5.9	6.1	4.9	5.9
Total Nitrogen	2.0	0.5	0.3	0.3	0.4	0.5	0.4	0.3	0.3	0.3	0.2	0.3
BOD	3.2	1.5	0.8	3.4	0.9	4.3	2.7	1.5	1.3	1.7	1.8	1.4
Organic Matter	0.5	0.8	1.2	0.4	0.2	1.0	0.9	0.8	0.4	0.7	4.1	0.5
Chlorophyll a	2.0	1.9	0.4	0.5	0.9	0.0	1.4	2.1	1.5	0.0	1.0	1.5

Apendix C. Continued.

Bank Full Width	11.8	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	7.9	8.0	7.0	7.6	7.8	8.8	8.8	7.8	8.0	8.2	7.3	7.5
	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.1
% Overstory	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.7	0.8	1.0	0.7	0.9
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	180.2	-	-	-	-	-	-	-	-	-	-	-
	1.6	-	-	-	-	-	-	-	-	-	-	-
Depth	47.5	47.8	60.5	48.0	50.0	72.1	74.2	64.3	61.5	57.2	57.9	52.7
	0.5	0.5	0.7	0.6	0.5	0.5	0.4	0.4	0.7	0.5	0.5	0.3
Flow	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	81.6	47.7	45.6	62.7	48.3	48.2	45.8	54.1	22.2	43.4	51.6	96.9
	3.7	1.5	1.9	2.8	1.5	1.8	1.0	1.7	0.8	1.3	1.9	2.7
Wood SA	4.9	5.4	3.5	5.8	4.4	4.9	4.4	4.2	2.8	3.8	5.4	10.7
	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Wood Number	7.0	13.3	6.2	8.5	5.1	8.8	5.8	4.9	5.0	7.4	8.3	10.8
	0.2	0.4	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.3
PSI	74.1	67.3	75.0	65.4	65.3	66.0	57.6	63.1	64.0	65.9	62.4	67.3
	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.1	0.2	0.2	0.3	0.2

Apendix C. Continued.

BLUSA3												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	26.3	22.7	18.7	13.4	10.6	11.2	15.2	17.0	20.2	22.4	24.1	24.7
Specific Cond	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
DO	8.0	9.0	9.6	9.5	10.8	9.5	9.1	9.8	9.7	7.9	7.1	7.7
pH	6.3	6.3	6.3	6.0	6.1	5.6	6.3	6.0	7.6	6.6	6.1	6.8
Turbidity	2.1	4.4	5.5	2.5	4.7	7.0	11.1	8.1	4.5	4.3	2.1	3.2
Slope	0.1	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	85.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.3	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	12.0	18.5	18.0	17.7	10.4	25.7	3.8	7.9	5.4	2.4	1.5	4.3
Pebble Number	14.0	25.0	46.0	31.0	13.0	13.0	31.0	29.0	36.0	11.0	8.0	34.0
% Coarse Substrate	49.4	0.1	28.1	2.7	19.1	0.9	29.2	28.9	6.7	49.2	26.6	21.9
% Sand Substrate	45.0	97.6	59.1	97.1	69.8	98.6	64.9	70.8	93.2	49.0	73.2	77.8
% Fine Substrate	5.5	2.3	12.7	0.2	11.1	0.5	5.9	0.2	0.1	1.8	0.1	0.3
Total Carbon	6.1	6.4	3.1	5.8	7.9	14.1	10.1	7.9	6.9	7.5	8.7	8.4
DOC	4.0	6.1	1.1	4.1	6.1	9.1	9.1	6.6	5.3	6.0	5.7	6.7
Total Nitrogen	2.0	0.5	0.3	0.1	0.2	0.7	0.4	0.3	0.2	0.3	0.1	0.4
BOD	3.8	2.3	2.5	1.3	2.3	2.1	3.0	1.5	1.0	1.8	2.5	1.4
Organic Matter	0.4	1.3	0.6	1.0	0.5	0.8	0.4	0.4	0.4	0.3	2.8	1.3
Chlorophyll a	2.8	1.6	1.0	0.4	1.8	0.0	0.2	1.1	0.8	0.7	0.6	1.0

Apendix C. Continued.

Bank Full Width	13.5	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	9.0	9.7	9.0	9.2	9.5	10.4	10.8	10.0	9.5	10.0	10.3	8.9
	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0
% Overstory	0.7	0.8	0.7	0.7	0.4	0.7	0.5	0.6	0.7	0.9	0.7	0.7
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	170.4	-	-	-	-	-	-	-	-	-	-	-
	0.8	-	-	-	-	-	-	-	-	-	-	-
Depth	50.3	48.3	48.4	48.6	48.4	81.5	69.9	64.3	57.9	63.0	55.2	49.9
	0.5	0.5	0.5	0.6	0.4	0.5	0.6	0.5	0.7	0.7	0.7	0.6
Flow	0.1	0.2	0.1	0.2	0.1	0.3	0.3	0.3	0.2	0.2	0.1	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	77.0	23.2	31.4	47.5	35.1	28.3	48.4	28.2	15.1	39.2	13.8	58.3
	3.5	0.7	1.2	1.9	1.0	1.0	1.3	0.9	0.6	1.5	0.5	4.0
Wood SA	5.3	4.5	3.9	4.6	4.5	2.6	5.1	4.3	3.2	4.2	2.2	4.7
	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2
Wood Number	11.8	21.8	12.1	13.2	9.8	4.8	12.1	11.4	10.5	7.0	7.0	15.4
	0.2	0.4	0.5	0.3	0.2	0.1	0.2	0.3	0.4	0.1	0.1	0.5
PSI	61.5	59.9	62.3	57.7	54.1	58.3	54.6	55.7	55.8	58.3	57.6	57.2
	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.3	0.3	0.3

Apendix C. Continued.

LAW1												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	24.7	23.7	17.3	11.9	12.8	10.8	11.5	16.5	21.3	22.2	23.1	24.7
Specific Cond	0.03	0.04	0.04	0.04	0.04	0.05	0.06	0.05	0.04	0.05	0.05	0.05
DO	7.0	8.4	9.7	9.7	9.0	9.8	10.0	11.0	7.4	7.4	6.6	5.8
pH	6.4	6.5	6.5	6.3	7.4	6.3	7.3	6.8	6.2	6.9	5.9	7.3
Turbidity	5.7	9.6	8.3	6.3	12.7	9.4	17.0	12.7	6.8	4.9	4.3	13.5
Slope	0.1	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	76.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.3	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	17.5	13.4	12.2	15.7	13.8	0.0	17.8	16.8	0.0	0.0	12.7	14.5
Pebble Number	8.0	25.0	20.0	14.0	25.0	0.0	12.0	13.0	0.0	0.0	9.0	22.0
% Coarse Substrate	5.5	12.4	14.4	15.4	1.9	2.9	2.5	0.8	0.6	10.8	8.4	1.9
% Sand Substrate	80.9	75.2	85.1	84.3	94.8	96.7	97.4	99.0	93.5	88.7	91.5	98.0
% Fine Substrate	13.6	12.4	0.5	0.3	3.4	0.4	0.1	0.2	5.9	0.4	0.1	0.1
Total Carbon	5.1	6.2	5.3	7.5	11.8	13.2	12.7	11.0	7.8	10.0	10.4	9.7
DOC	2.1	5.5	2.8	4.9	8.7	10.0	10.8	7.9	4.6	7.5	8.1	6.9
Total Nitrogen	2.1	0.3	0.2	0.2	0.3	1.3	0.9	0.8	0.6	0.5	0.7	0.7
BOD	4.3	5.1	4.4	1.2	6.0	6.5	6.0	7.4	1.5	5.3	4.9	3.7
Organic Matter	1.2	1.3	1.9	0.9	1.3	3.9	1.6	1.1	1.5	0.6	2.2	1.0
Chlorophyll a	2.1	0.6	0.8	8.7	1.8	1.5	0.0	0.3	0.5	0.3	0.0	2.4

Apendix C. Continued.

Bank Full Width	9.7	-	-	-	-	-	-	-	-	-	-	-
	0.0	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	5.7	6.9	5.2	6.0	5.7	6.3	6.7	6.7	5.7	5.9	5.5	5.3
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Overstory	0.9	0.9	0.8	0.8	0.6	0.6	0.5	0.8	0.9	0.8	0.8	0.9
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	133.1	-	-	-	-	-	-	-	-	-	-	-
	0.2	-	-	-	-	-	-	-	-	-	-	-
Depth	34.3	42.7	35.7	34.0	40.3	46.1	44.6	48.9	40.3	42.7	36.7	30.4
	0.4	0.6	0.6	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.7
Flow	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	195.1	139.2	152.4	110.4	147.5	123.4	72.6	389.8	139.7	64.6	74.2	127.6
	5.9	4.4	4.4	2.6	4.3	3.3	2.5	28.5	4.5	0.9	2.3	5.5
Wood SA	10.9	11.8	14.0	9.8	11.4	10.6	8.3	10.1	20.3	10.8	9.8	7.7
	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.7	0.1	0.3	0.2
Wood Number	9.5	21.6	18.4	23.0	12.5	13.5	13.5	7.2	31.4	20.7	16.2	10.2
	0.2	0.5	0.3	0.0	0.3	0.2	0.2	0.1	0.8	0.4	0.3	0.3
PSI	71.9	66.6	67.3	62.5	59.7	63.6	52.8	59.6	56.2	57.2	62.1	68.6
	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2

Apendix C. Continued.

LAW2												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	25.8	23.4	18.6	12.7	9.7	11.7	12.5	17.6	17.3	20.6	22.9	24.6
Specific Cond	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.03
DO	8.4	9.4	10.1	9.7	10.3	9.6	10.2	11.7	9.4	8.4	7.4	8.6
pH	6.4	6.5	6.6	6.3	6.0	6.9	6.9	7.0	6.5	6.7	6.2	7.3
Turbidity	3.0	8.9	29.6	2.6	4.5	9.9	15.2	18.5	6.7	6.2	3.6	4.5
Slope	0.0	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	43.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.1	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	15.0	13.4	13.3	8.2	15.0	10.5	0.0	0.0	17.1	2.0	9.8	13.6
Pebble Number	7.0	6.0	5.0	9.0	1.0	2.0	0.0	0.0	3.0	1.0	8.0	14.0
% Coarse Substrate	0.3	34.2	4.5	1.4	5.7	3.4	2.4	1.3	7.3	18.8	14.7	19.3
% Sand Substrate	87.6	59.1	94.4	98.2	86.8	96.4	71.4	98.4	91.9	80.3	85.2	80.6
% Fine Substrate	12.2	6.7	1.1	0.3	7.5	0.2	26.2	0.3	0.8	0.9	0.2	0.1
Total Carbon	5.7	5.8	3.8	6.1	10.4	13.1	11.1	8.3	6.4	6.6	8.4	8.1
DOC	3.2	6.0	2.0	4.1	7.3	9.7	9.3	6.5	4.0	5.0	5.5	5.8
Total Nitrogen	2.1	1.0	0.2	0.2	0.3	0.9	0.7	0.5	0.5	0.4	0.6	0.7
BOD	3.5	6.7	4.9	0.5	6.0	2.7	4.2	1.7	3.0	5.5	3.8	5.0
Organic Matter	1.8	1.3	1.3	2.8	0.4	1.9	2.5	1.9	1.1	1.1	0.6	1.1
Chlorophyll a	1.5	2.5	2.5	0.1	0.6	0.2	0.5	0.9	0.0	1.2	2.3	4.0

Apendix C. Continued.

Bank Full Width	14.2	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	9.4	9.1	8.0	8.0	8.4	9.0	9.8	9.8	9.0	8.6	8.6	8.1
	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1
% Overstory	0.9	0.9	0.8	0.8	0.7	0.6	0.5	0.9	0.9	0.8	0.8	0.8
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	184.1	-	-	-	-	-	-	-	-	-	-	-
	0.6	-	-	-	-	-	-	-	-	-	-	-
Depth	51.1	52.5	52.7	56.4	54.6	70.2	74.3	71.2	59.2	59.7	51.5	45.5
	0.5	0.7	0.5	0.5	0.3	0.5	0.5	0.4	0.6	0.4	0.4	0.4
Flow	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	77.4	85.7	59.8	71.2	82.4	46.1	27.3	65.3	35.1	71.3	58.8	79.0
	2.8	4.0	2.2	2.3	3.2	1.8	0.8	1.8	1.2	1.5	1.4	2.3
Wood SA	5.3	6.9	6.4	6.5	6.9	5.7	4.6	8.0	5.4	7.7	6.8	8.0
	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2
Wood Number	9.4	20.0	12.3	12.3	10.4	11.7	10.8	16.3	17.4	18.2	15.5	15.9
	0.2	0.5	0.3	0.3	0.2	0.2	0.3	0.2	0.3	0.4	0.2	0.3
PSI	74.1	74.8	69.4	62.1	59.7	66.7	62.9	56.7	59.0	60.6	63.5	67.5
	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1

Apendix C. Continued.

LAW3												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	27.6	22.6	17.3	13.8	10.7	11.1	14.3	19.7	20.7	20.6	25.6	27.7
Specific Cond	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04	0.05	0.04	0.04
DO	9.3	9.3	9.7	8.9	9.8	9.8	10.4	12.1	9.6	8.5	9.0	10.0
pH	6.3	6.3	6.2	6.0	6.7	5.4	6.9	7.0	6.6	6.7	6.2	7.3
Turbidity	2.0	5.5	3.5	2.6	3.4	10.0	12.4	17.5	5.5	4.8	3.1	3.3
Slope	0.1	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	82.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.2	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	15.8	17.3	16.0	20.6	17.8	16.7	18.3	16.6	15.6	2.1	12.0	19.1
Pebble Number	44.0	50.0	42.0	63.0	56.0	69.0	63.0	83.0	81.0	66.0	58.0	81.0
% Coarse Substrate	45.9	10.7	52.5	67.6	59.6	52.3	67.3	46.4	53.2	41.2	54.7	27.7
% Sand Substrate	48.4	83.7	43.7	30.3	36.8	43.5	29.6	50.7	41.5	59.6	45.2	72.3
% Fine Substrate	5.7	5.6	3.8	2.1	3.5	4.2	3.1	2.9	5.3	-0.9	0.1	0.1
Total Carbon	6.8	7.4	4.2	6.3	12.1	12.1	11.4	7.7	7.1	6.4	9.6	8.6
DOC	3.3	6.6	1.9	4.2	10.0	9.9	9.4	5.8	5.1	4.8	7.4	6.0
Total Nitrogen	2.2	0.6	0.2	0.3	0.2	0.9	0.9	0.7	0.5	0.5	0.6	0.6
BOD	4.1	7.6	4.5	0.6	5.4	2.2	3.6	1.8	1.4	4.0	3.4	4.6
Organic Matter	0.1	0.3	0.7	2.1	0.4	0.7	0.4	0.5	0.4	0.5	0.5	0.2
Chlorophyll a	4.1	14.9	8.0	0.4	3.1	1.5	1.9	1.6	2.3	6.7	2.9	3.4

Apendix C. Continued.

Bank Full Width	17.9	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	9.5	10.4	9.9	9.4	9.6	11.5	10.8	11.9	12.8	11.8	11.7	11.5
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
% Overstory	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	131.4	-	-	-	-	-	-	-	-	-	-	-
	0.7	-	-	-	-	-	-	-	-	-	-	-
Depth	47.3	48.9	49.9	47.9	46.9	59.3	59.9	50.9	40.2	40.9	42.2	33.3
	0.6	0.5	0.6	0.5	0.6	0.7	0.6	0.6	0.6	0.4	0.5	0.5
Flow	0.2	0.3	0.2	0.2	0.2	0.4	0.4	0.4	0.2	0.4	0.2	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	13.7	13.9	4.7	8.4	17.8	19.8	20.0	9.6	6.1	12.5	7.1	20.5
	0.9	0.8	0.2	0.4	0.9	1.1	0.8	0.3	0.4	0.4	0.2	1.4
Wood SA	1.0	1.3	1.3	1.1	1.8	2.6	1.9	2.1	0.9	1.4	1.9	1.9
	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Wood Number	1.8	3.4	4.4	2.4	3.4	5.9	4.2	7.5	6.3	5.0	10.2	5.9
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.5	0.1
PSI	49.0	41.5	44.4	44.9	42.4	46.7	47.3	52.1	47.1	50.7	45.1	46.1
	0.3	0.1	0.1	0.2	0.1	0.2	0.2	0.3	0.3	0.2	0.3	0.2

Apendix C. Continued.

PUSH1												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	23.5	21.6	17.4	16.8	12.1	10.6	13.4	17.3	17.5	20.9	22.7	23.0
Specific Cond	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06
DO	8.1	10.2	10.3	8.7	10.5	9.5	3.8	9.8	8.8	8.3	7.6	7.4
pH	6.2	6.3	6.3	6.1	6.4	5.1	7.1	6.2	6.9	6.8	6.6	7.1
Turbidity	5.8	6.2	5.1	6.2	4.4	11.4	17.6	6.1	6.5	5.7	3.3	7.2
Slope	0.0	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	65.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.2	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	13.3	11.2	10.7	9.2	8.4	8.0	8.1	9.6	15.9	2.1	3.6	0.0
Pebble Number	16.0	11.0	15.0	2.0	18.0	1.0	3.0	19.0	22.0	6.0	22.0	0.0
% Coarse Substrate	0.1	0.6	27.1	2.2	6.5	1.1	2.0	1.3	4.7	10.8	7.5	4.3
% Sand Substrate	69.6	84.4	61.4	97.6	82.8	98.5	90.0	98.4	95.1	88.7	92.2	95.5
% Fine Substrate	30.4	15.0	11.5	0.2	10.8	0.5	8.0	0.2	0.3	0.4	0.3	0.2
Total Carbon	5.5	4.0	3.3	4.6	9.2	9.0	6.9	5.7	6.6	4.1	10.6	7.7
DOC	3.0	3.4	1.4	2.8	6.4	6.6	4.8	3.4	3.4	2.5	7.9	5.2
Total Nitrogen	2.3	0.3	0.1	0.5	0.1	1.0	0.8	0.6	0.6	0.4	0.7	1.0
BOD	3.9	7.1	4.2	0.4	4.8	1.8	5.9	1.5	3.2	3.5	3.7	5.7
Organic Matter	0.6	0.9	3.4	0.7	2.0	0.7	1.8	2.3	0.7	0.7	0.7	1.0
Chlorophyll a	2.7	3.5	1.5	4.3	2.2	3.7	0.6	1.9	0.0	1.0	1.1	4.2

Apendix C. Continued.

Bank Full Width	15.5	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	12.3	11.3	12.1	10.6	11.7	11.8	12.1	11.7	11.8	10.7	11.3	10.8
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
% Overstory	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.6	0.8	0.9
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	163.3	-	-	-	-	-	-	-	-	-	-	-
	0.5	-	-	-	-	-	-	-	-	-	-	-
Depth	51.9	49.6	42.7	45.4	44.8	59.1	54.6	56.8	49.9	51.9	52.2	53.8
	0.6	0.6	0.5	0.6	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.9
Flow	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	15.8	18.2	34.4	11.5	23.0	12.1	19.5	32.3	18.8	14.1	28.5	25.5
	0.7	0.8	2.2	0.4	0.7	0.4	0.7	1.9	0.4	0.5	1.4	1.4
Wood SA	2.4	2.4	2.3	2.3	3.4	2.0	2.6	3.1	2.7	2.9	3.4	2.8
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wood Number	10.3	7.8	6.8	9.7	9.1	6.1	9.2	8.6	8.5	13.4	11.2	7.7
	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2
PSI	66.7	68.3	65.5	61.6	57.9	60.7	54.8	55.8	56.5	59.5	58.9	62.9
	0.3	0.2	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.4	0.3

Apendix C. Continued.

PUSH2												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	23.9	22.0	16.2	16.2	10.7	10.8	16.9	16.9	18.4	22.2	23.5	25.0
Specific Cond	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
DO	8.3	10.6	10.5	8.8	11.1	9.9	9.1	9.8	9.3	8.8	7.9	7.9
pH	6.5	6.6	6.3	6.3	6.7	5.4	6.5	6.7	7.1	7.0	6.7	7.3
Turbidity	8.8	6.5	7.9	5.3	4.1	14.0	9.5	6.1	5.9	5.4	4.7	4.7
Slope	0.0	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	96.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.2	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	15.3	10.0	11.8	18.7	9.1	12.7	12.4	15.5	14.5	2.1	9.2	8.8
Pebble Number	27.0	32.0	25.0	24.0	18.0	4.0	46.0	22.0	36.0	18.0	42.0	15.0
% Coarse Substrate	5.2	23.1	16.7	7.3	16.8	1.7	23.1	28.6	10.4	18.8	5.7	4.7
% Sand Substrate	86.8	65.8	82.0	92.5	76.5	98.0	64.1	70.5	89.5	80.3	94.2	95.1
% Fine Substrate	8.0	11.1	1.3	0.2	6.8	0.2	12.8	0.9	0.1	0.9	0.1	0.2
Total Carbon	3.9	4.5	4.1	5.0	9.9	10.8	7.6	6.1	6.2	4.7	9.6	8.2
DOC	1.3	4.1	1.3	3.4	5.8	8.1	5.6	4.1	3.7	3.2	7.2	5.8
Total Nitrogen	2.3	0.6	0.1	0.3	0.7	0.9	0.8	0.7	0.6	0.5	0.5	0.8
BOD	1.2	7.9	5.1	0.1	4.7	3.2	6.8	4.4	3.4	4.2	3.3	4.2
Organic Matter	4.0	1.6	0.7	1.3	0.6	0.4	0.6	0.5	0.2	0.3	0.3	0.4
Chlorophyll a	1.2	3.4	4.9	0.4	1.0	0.2	1.8	1.1	2.9	1.7	3.0	2.5

Apendix C. Continued.

Bank Full Width	19.8	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	14.7	13.7	14.4	14.5	13.7	15.0	13.7	13.4	13.6	13.2	14.6	13.4
	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
% Overstory	0.4	0.5	0.4	0.5	0.3	0.2	0.3	0.3	0.4	0.2	0.4	0.4
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	164.8	-	-	-	-	-	-	-	-	-	-	-
	1.0	-	-	-	-	-	-	-	-	-	-	-
Depth	61.7	58.7	60.9	63.5	62.4	79.3	75.7	75.7	67.9	61.8	57.7	61.2
	0.6	0.4	0.4	0.4	0.4	0.5	0.7	0.5	0.4	0.5	0.3	0.6
Flow	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	58.3	59.0	60.2	22.1	11.8	10.4	37.0	18.9	9.5	12.8	20.3	45.2
	3.8	3.8	1.9	1.1	0.5	0.5	1.8	0.9	0.4	0.8	0.9	1.7
Wood SA	2.5	2.2	2.8	2.4	1.5	1.2	2.2	1.8	1.0	1.0	1.9	7.5
	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.4
Wood Number	7.5	4.0	6.3	9.0	5.2	3.7	5.1	4.3	2.8	5.6	5.3	8.2
	0.2	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
PSI	51.2	49.1	46.9	48.5	49.7	51.2	46.1	54.2	50.5	47.4	45.1	44.8
	0.3	0.2	0.4	0.3	0.2	0.2	0.3	0.1	0.2	0.3	0.3	0.3

Apendix C. Continued.

PUSH3												
	8/07	9/07	10/07	11/07	12/07	1/08	2/08	3/08	4/08	5/08	6/08	7/08
Temperature	28.5	22.0	21.9	16.1	10.0	11.4	17.2	17.8	20.0	23.2	24.7	28.2
Specific Cond	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
DO	9.4	10.5	8.7	10.2	13.0	9.7	9.8	9.8	9.8	8.9	7.8	7.9
pH	6.6	6.6	6.6	6.5	5.8	5.5	6.3	6.4	7.7	6.8	6.7	7.1
Turbidity	2.9	7.0	5.7	3.8	5.1	11.5	21.2	7.3	4.5	4.1	3.8	3.6
Slope	0.1	-	-	-	-	-	-	-	-	-	-	-
Sinuosity	88.0	-	-	-	-	-	-	-	-	-	-	-
Entrenchment	0.2	-	-	-	-	-	-	-	-	-	-	-
Pebble Diameter	19.9	15.1	18.9	13.2	15.5	18.5	15.2	18.4	18.1	23.7	13.3	13.4
Pebble Number	98.0	72.0	80.0	92.0	84.0	67.0	66.0	69.0	74.0	59.0	54.0	74.0
% Coarse Substrate	63.7	24.8	53.2	24.7	54.8	34.9	6.7	40.4	49.2	37.1	40.7	57.2
% Sand Substrate	26.8	63.8	34.3	74.6	37.9	64.8	91.1	59.4	45.0	53.6	59.0	42.6
% Fine Substrate	9.5	11.4	12.5	0.6	7.3	0.4	2.2	0.2	5.8	9.3	0.2	0.2
Total Carbon	4.2	4.2	3.3	6.2	12.2	11.8	8.6	6.9	6.5	4.9	9.3	8.0
DOC	2.0	3.5	1.4	3.4	8.1	9.4	6.8	5.2	3.8	3.2	6.9	6.2
Total Nitrogen	2.2	0.6	0.1	0.4	0.4	0.8	0.6	0.6	0.3	0.4	0.6	0.7
BOD	4.3	6.9	4.4	1.5	5.4	2.2	6.6	7.4	4.4	4.3	4.4	5.2
Organic Matter	0.3	0.9	0.7	0.7	0.4	0.3	0.2	0.6	0.4	0.6	0.3	0.3
Chlorophyll a	5.6	3.6	4.3	8.8	0.8	2.6	1.9	0.4	2.4	2.9	4.6	6.2

Apendix C. Continued.

Bank Full Width	19.8	-	-	-	-	-	-	-	-	-	-	-
	0.1	-	-	-	-	-	-	-	-	-	-	-
Wetted Width	9.7	10.1	10.0	9.9	10.6	12.2	11.4	12.6	10.7	10.7	9.9	9.7
	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
% Overstory	0.5	0.5	0.4	0.4	0.3	0.2	0.2	0.3	0.4	0.2	0.5	0.5
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bank Full Depth	150.7	-	-	-	-	-	-	-	-	-	-	-
	0.9	-	-	-	-	-	-	-	-	-	-	-
Depth	46.5	47.6	45.5	47.7	44.7	66.1	62.2	58.7	50.3	46.8	43.5	45.0
	0.5	0.5	0.5	0.5	0.5	0.3	0.5	0.4	0.4	0.4	0.5	0.5
Flow	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.4
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood Volume	14.0	66.1	21.7	17.4	33.0	24.3	50.2	32.5	17.6	4.8	51.5	43.6
	0.7	2.3	0.8	0.6	1.6	1.2	2.6	2.0	0.7	0.2	2.1	1.8
Wood SA	1.8	3.9	2.4	2.7	2.3	2.0	2.6	2.0	1.9	3.6	3.0	2.7
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1
Wood Number	7.1	8.9	6.1	8.0	4.7	7.2	3.8	3.9	4.3	4.4	5.1	5.1
	0.2	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
PSI	48.8	46.8	45.5	45.9	47.7	54.8	45.9	53.3	45.1	46.6	43.4	46.8
	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.3	0.3	0.2	0.4

Vita

Peter Demetrios Markos was born in Cleveland, Ohio on June, 1979. His parents are Demetrios P. Markos and Hrisoula S. Markos who both immigrated from Nemouta, Greece. He attended public school at Lakewood High School and graduated in 1997. He entered Ohio University in 2002 and graduated in 2005 with a Bachelor of Science degree in biology and a Bachelor of Art degree in philosophy. In January 2007 he entered graduate school at Louisiana State University and is currently a candidate for the degree of Masters of Science in fisheries from the School of Renewable Natural Resources.